

Mirror Neurons and the Evolution of Brain and Language

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On the evolutionary origin of language*

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1. Origin vs. evolution of language

In recent years there has been a flurry of scholarly activities on the origin of language. New scholarly societies have been formed; conferences have been organized; books, edited and written. In all of these activities, a common theme prevails as it appears in the titles of conferences, articles and books. This common theme is, "the evolution of language". It implies that language was the communicative behavior of hominids. Yet no one would assume that all our phylogenetic ancestors had language, if language designates the casual, spoken language of anatomically modern humans.¹ Even if we confine ourselves to the family of hominidae, no one would assume that the earliest hominids such as the *Ardipithecus ramidus* and the *Australopithecines*,² had language. It was about 6–7 million years ago that the first hominids began to evolve away from the quadrupedal, knuckle-walking great apes by embarking upon the evolutionary pathway of developing bipedal locomotion.³ At the beginning, they were on average a little more than 1 meter in height and 30 kilograms in weight with a cranial capacity at approximately 400 c.c. Among contemporary primates, they would be much more ape-like than human-like. Given their anatomical difference from humans, it seems sensible to consider their communicative behavior distinct from human casual, spoken language. It follows, then, the evolution of their communicative behavior is not the evolution of language. Nevertheless, their communicative behavior evolved, as did the communicative behavior of all early hominids evolve toward the emergence of language. The investigation of the origin of language is, therefore, an enterprise concerned with the evolution of the communicative behavior of our hominid ancestors, NOT the evolution of language. The evolution of language concerns linguistic change. It is diachronic linguistics. The origin of language is not diachronic linguistics. Chronologically the study of the evolution of language starts from the time when

language emerged, whereas the study of the origin of language ends at the point in time when language emerged. This distinction does not belittle the significance of the research effort probing into the older and older layers of human language. Nor does it dismiss the importance of the proto-human language if and when its features can be inferred. The distinction must be made for one important reason, and that is the ways casual, spoken language changes and the ways hominid communicative behavior changes are fundamentally different.

2. The evolutionary change of communication vs. linguistic change

The fundamental difference lies in the fact that early hominid communicative behavior, not human language, is subject to the constraints of Darwinian evolution. In other words, the evolution of our hominid ancestors' communicative behavior involved natural selection and genetic mutation. A change of their communicative behavior in the direction toward language was adaptive in the sense that it enhanced their life expectancy and their reproductive success. Those hominids who made the change achieved a higher level of fitness than those hominids who failed to make the change. The reason is that a change moving the hominids' communicative behavior one step closer to human language would imply greater communicative efficiency. Greater communicative efficiency would entail greater ease with which valuable experience and knowledge could be passed from one individual to another and from one generation to another. Rapid and efficient transmission of knowledge conferred an immense competitive advantage to the hominids for securing resources and possibly vanquishing others, including other species of hominids whose communicative behavior was less developed in the direction toward language. Given that hominids within the genus of *Homo* and possibly most gracile species of the *Australopithecine* genus are generalists who did not specialize in any specific ecological niche, the competitive advantage conferred by a more effective communicative behavior may explain why modern humans are the only surviving species within the taxonomic family of hominids. In the animal kingdom, the only other case of a single surviving species in a family is the ant-eating African aardvark! Typically different species of a family specialize in different ecological niches. Consider, for example, the felines and the Darwinian finches of the Galapagos. When two hominid species happened to co-exist as generalists and the communicative behavior of one species were more effective than that of the other species, there would be a good possibility that the communicatively more advanced species would eliminate the other through competition!

The change of hominid communicative behavior toward human language began with symbolic communication. By symbolic communication, we mean the use

of symbols each of which represents directly, consistently and exclusively an entity in the world. The emergence of the first symbolic communicative signal among hominids is not only an important evolutionary landmark but also represents a quantum leap from non-human primate communication. Prior to this landmark development, the communicative signals of hominids should not be qualitatively different from non-human primate communicative signals. Non-human primate communicative signals are not symbolic. They have functions, not meanings. Consider, for example, the well-known warning calls of the African vervet monkeys. One indicates the warning uttered by the signaler when it notices the presence of a reptilian predator. Even though such a warning call differs from the other warning calls connected to the presence of a mammalian predator, an avian predator, a Masai herdsman, or some other potentially dangerous animals, it is not a symbol that represents a reptilian predator. It merely indicates the function of the vocalization in the presence of a reptilian predator. Seyfarth and Cheney (1999) note that vocal production, i.e. delivery of acoustically defined calls, among apes and monkeys appears fully formed shortly after birth, suggesting that vocal production may be largely innate. In addition, Aitken (1981) and Pandya et al. (1988) conducted experiments on monkeys showing that their vocal production was mediated primarily by the central (periaqueductal) gray area of the mid-brain, a phylogenetically very old set of neurons responsible for arousal and motivational states in all vertebrates. Although Seyfarth and Cheney (1999) point out that the development of vocal usage (*vis-à-vis* production) as well as the development of responses to the calls of others do require some learning at least for vervet monkeys, their study does not alter the fact that (1) non-human primate communicative signals are not symbolic,⁴ and (2) the production of non-human primate communication is mediated primarily by the central gray area of the mid-brain.⁵ In the case of vervet monkey's warning calls, the only role of the neocortex involves associating a particular involuntary vocalization with a specific situation. The vocalization is involuntary because it is probably associated with fear aroused by the situation.⁶ Hence an infant vervet possesses the adult repertoire of vocalization. The learning during ontological development involves the correct coupling of one involuntary vocalization with one specific dangerous situation. Each expression can be graded according to intensity. But it is only the coupling process that is mediated by the neocortex, and this coupling process, according to Seyfarth and Cheney, requires learning. The neural mechanism we have just sketched for non-human primate communication contrasts sharply with the neural mechanism of the production of casual, spoken language. The production of casual, spoken language is primarily mediated by the neocortex. The emotional/motivational state of the speaker can be viewed as a coterminous but neurologically separate dimension of speech expressed primarily in prosody. It is, therefore, not surprising that participants in casual spoken language can talk about things that are remote in time and space from the

location of the conversation. This is the “displacement” feature of human language that Charles Hockett (1960) pointed out. It does not exist in non-human primate communication because a non-human primate communicative signal tends to be associated with the emotional or motivational reaction to a particular situation including the animal’s own internal hormonal state.

Even though the onset and expansion of symbolic communication in hominid evolution represent a break from non-human primate communication, the process of change before the origin of language remains an evolutionary change. Such a change typically involves a slow and gradual Darwinian process that requires hundreds and thousands of generations.⁷ It is adaptive in the sense that it improves the fitness of the hominids. Linguistic change, the change of language after its origin, however, is by and large tied to society and culture. It has nothing to do with genetic mutation, natural selection, life expectancy or reproductive success. Language changes constantly. Our pronunciation changes, our vocabulary changes, our ways of speaking change, and our grammar changes. Confusing the evolution of language with the origin of language may mislead researchers into attributing features of language to the communicative behavior of my evolutionary ancestors before the emergence of language.

3. The emergence of language vs. the emergence of anatomically modern human

Many paleoanthropologists believe that language emerged together with anatomically modern humans. That is, casual spoken language coincided with the emergence of anatomically modern humans in Africa some 150–130 thousand years ago (Walker & Shipman 1996). However, there is a confluence of evidence from paleodemography, molecular genetics, and a variety of archaeological discoveries, which suggest that the crystallization of language may not have coincided with the emergence of anatomically modern humans.⁸ This confluence of evidence has led us to postulate that language emerged around 80–60 thousand years ago, several tens of thousand years after the appearance of anatomically modern humans. We will briefly summarize the evidence:

1. Around 60,000–40,000 years ago, the size of human population began its first explosive increase. According to F. A. Hassan’s study of demographic archaeology, the dramatic increase in human population started at the end of the Middle Paleolithic period at about 40,000 years ago (Hassan 1981). Figure 1 is modeled after Hassan (1981:196).

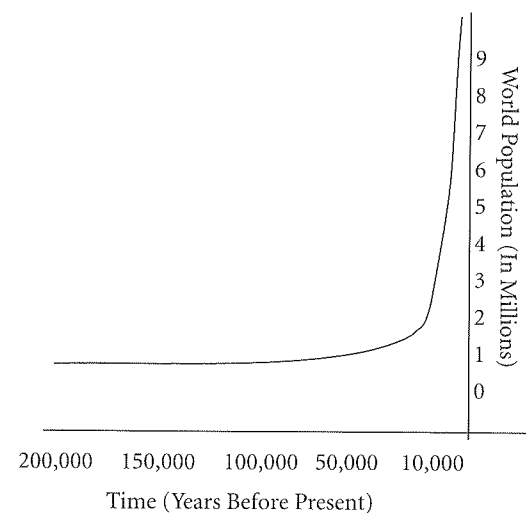


Figure 1. Estimates of human population

The French paleo-demographer, Jean-Noel Biraben, independently arrived at a similar conclusion in his “*Essai sur l’évolution du nombre des Hommes*”, (1979). According to Biraben’s estimate, the world population increased by 500% around 40,000 years ago.

The population explosion during the period of 60,000–40,000 years ago is also confirmed by the study of mitochondria DNA (m-DNA) phylogeny (Sherry et al. 1994) on the basis of polymorphism and average mutation rate.⁹

The second major population increase in human history occurred at the beginning of the Neolithic period, around 10,000 years ago. The driving force behind this second population explosion is well known: the development of agriculture.

Question: What caused the first explosion of human population between 60,000 to 40,000 years ago?

Whatever the cause may be, it must have the potential of facilitating all aspects of human activity and social interaction and consequently enhancing human life expectancy and survival rate.

2. At around 40,000 year before present, a “Big Bang” of art occurred. The oldest preserved rock paintings discovered to date are the red ochre figures of half-human and half-beast found in the Fumane Cave northwest of Verona at 36,500–32,000 years old and the Grotte Chauvet paintings of animals at approximately 32,000 years old (Balter 1999). The artistic sophistication of the Grotte Chauvet paintings includes such refined techniques as shading and perspective, suggesting a long period of the development of artistic concepts and

skills before the creation of the Grotte Chauvet painting. Personal ornamentation is another facet of the Big Bang of art. The oldest ornaments in the form of beads and pendants carved out of ivory are 35,000 years old (White 1986). These ornaments are conceptually, symbolically and technically complex, suggesting the work of a modern human mind.

Question: Is the Big Bang of art a consequence of the emergence of language, which facilitates my intellectual capability?

- At around 50,000–40,000 years ago, the beginning of the Upper Paleolithic period, tools, like art, in stark contrast to all other earlier tool kits, began an unprecedented acceleration of diversification and specialization. This development in tool variety and complexity was worldwide. If we plot the trajectory of change in stone-tool technologies in terms of number of distinct tool types against time, the curve obtained strongly resembles that of the population change. It shows a long stasis characterized by a relative flat line until the end of the Middle Paleolithic and the beginning of Upper Paleolithic when the curve begins to shoot up vertically. Figure 2 is modeled after Lewin (1993:33).¹⁰

The Upper Paleolithic tools include hafted blades that are at least twice as long as they are wide and numerous types of hafted small geometrically shaped tools such as chisels and files for carving and making bone instruments. They indicate a level of sophistication involving design and symbolism previously unattained in hominid history.

Question: What is the reason behind this explosive development of tools?

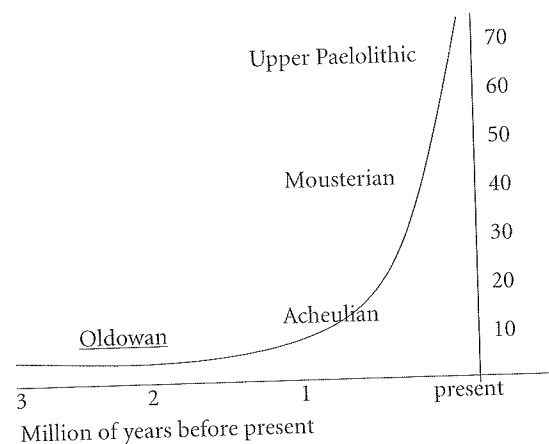


Figure 2. Number of distinct stone tools in hominid history

- The colonization of Australia occurred approximately 60,000 years ago. At the time, because of glaciation, Australia, Papua New Guinea and Tasmania formed one continuous land mass, while many of the present day islands of the Indonesia archipelago were connected with the Malaysia peninsula of Asia. Reaching Australia from Asia entailed the crossing of deep, fast-moving ocean water of approximately 100 kilometers. Such sea-crossing required social organization, collaborative effort, sophisticated planning, some skills, equipment and knowledge of navigation.

Question: What enabled humans to cross deep, fast-moving ocean water at that time but not before?

To sum up, these four pieces of evidence collectively point to a new cognitive capacity for sophisticated culture emerging during the period of 80,000–60,000 years ago. We cannot attribute this new cognitive capability to a larger brain, because human cranial capacity, if anything, has decreased since the dawn of anatomically modern human at around 150,000–120,000 years ago. In fact, the significant time gap between the first occurrence of anatomically modern humans and the first indication of a capacity for modern culture prompted Donald Johanson and Blake Edgar to pose the following question in their 1996 book, "From Lucy to Language",

This is one of the key unanswered questions in paleoanthropology today. Is it possible that the brains of early *Homo sapiens* were simply not yet wired for sophisticated culture? The modern capacity for culture seems to have emerged around 50,000 year ago, and with it, behaviorally modern humans who were capable of populating the globe. (Johanson & Edgar 1996:43)

Interestingly, the noted paleoanthropologist, Richard Klein, made a similar observation. Klein suggested that a *hidden evolution* of the brain, unrelated to its size and shape took place some 50,000 years ago, and that hidden evolution accounted for human's modern capacity for sophisticated culture and cognition (Klein 1989).

We submit that Klein's notion of a hidden evolution of the brain is exactly the same as the answer to the question posed by Johanson and Edgar, and the answer to Johanson and Edgar's question is also the answer to the four questions we have posed in my discussion of the confluent evidence. In our opinion, Klein's "hidden evolution of the brain" is a new deployment of cognitive ability brought about by the emergence of language. In other words, the crystallization of hominid communicative behavior into language is the underlying reason for all of the three pieces of evidence: the first and sudden surge of human population, the Great Bang of art, the explosive development of tools, and the crossing of deep, fast-moving ocean water separating Asia from Australia.

If language emerged after the arrival of anatomically modern humans, how and when it emerged? What are the mechanisms underlying the evolution of ho-

minid communicative behavior? According to our research, there are three mechanisms and four processes of evolution that are especially important. We will briefly sketch these three mechanisms and four processes.

4. Four evolutionary processes leading to the emergence of language

4.1 Reduction of the gastrointestinal tract

The reduction of the gastrointestinal tract is a necessary concomitant development of the increase in encephalization in hominid evolution. The reason is that an enlarged brain consumes an enormous amount of energy that has to come at the expense of some part of a homeostatic system of the hominid anatomy. The brain of a newborn infant, for instance, consumes 60% of the energy it takes in. Leslie Aiello and Peter Wheeler provide detailed analysis of this evolutionary process in a series of papers from 1995 to 1998. What enables the G.I. tract to decrease in hominid evolution is the change of diet. The change of diet in hominid history is inferred from archaeological evidence, the size of the fossilized jaw and the detailed properties of the fossilized teeth: their size, shape, striation, surface structure and the thickness of the enamel. The change is in the direction of greater nutritional value. Increased nutrition of ingested food facilitated the evolutionary process of decreasing the G.I. tract. Meat and sea food, of course, are the most nutrient-rich food. They became part of the diet of hominids in the genus *Homo*. Cooked food also facilitates digestion and makes it possible for the shrinking of the G.I. tract. Cooking can also enhance the sugar content of a variety of tubers. However, the earliest uncontroversial date for hearth is 400,000–300,000 year before present. Lee Berger claims that hearth existed in one of the hominid site in South Africa at approximately 900,000 years before present (Berger 2000). If Berger is correct about the South African hearth, cooked food might very well have played a role in the reduction of the G.I. tract in hominid evolution. A diet of 60% cooked tubers, about the proportion used in modern native African diet according to Wrangham et al. (1999), will increase caloric intake by approximately 43%. Wrangham and his colleague estimates that every square kilometer in Tanzania's savanna woodland, similar to the habitat of most early hominids, contains 40,000 kilograms of tubers today. They argue that cooked tubers, more so than meat, made possible the evolution of large brain, smaller teeth, shorter arms and longer legs, and even male-female bonding. The hypothesis put forth by Wrangham et al. is supported by the thesis that women, especially grandmothers, played a critical role in the evolution of *Homo erectus* by being the food gatherers (O'Connell et al. 1999).

4.2 Enlargement of the vertebral canal

Ann MacLarnon and Gwen Hewitt (1999), provides detailed analysis and convincing arguments to demonstrate that the thoracic vertebral canal enlarged in hominid evolution during the period of 1.6 million years ago to 150,000 years ago for the purpose of enhancing thoracic innervation of the intercostal muscles controlling breathing during speech. Their analysis demonstrates that all other possible reasons for the enlargement of the vertebral canal were invalid. In other words, the anatomical evolutionary process of enlarging the vertebral canal in hominid history is an adaptation to enhance the vocalization capability.

4.3 Descent of the larynx

The descent of the larynx is another gradual evolutionary process that occurred among the species of the genus *Homo*. It resulted in the gradual formation of an L-shaped vocal tract which serves to facilitate articulation. The fossil evidence of this process is poor because the key to the descent of the larynx is a specially shaped hyoid bone. Even in modern humans, the hyoid bone is miniscule. Fossil remain of the hyoid bone is, therefore, predictably scarce. But we do know from the paper written by Arensburg in 1990, that the Kebara Neanderthal in Israel possessed the specific hyoid bone required by a descended larynx.

4.4 Increase in encephalization

The large size of the human brain in comparison to other primates is prominently manifested in the neocortex.¹¹ The neocortex, the newest outer "skin" or "bark" in evolutionary terms, plays a critical role in all human cognitive behaviors. Because of its enormous size, it endows human beings with a prodigious cognitive memory and other capabilities.¹² A prodigious cognitive memory is a pre-requisite for language because, beyond vocabulary and grammar, every language has an enormous set of idiosyncratic ways of saying things. Let us explain.

Any person who is fluent in two or more unrelated languages or more is likely to have noticed that being fluent in a language requires much more than internalizing the grammar and acquiring a good vocabulary of that language. One needs to know how to say things in a language, and how to say things in a language requires an enormous amount of knowledge beyond syntax and morphology. A person can master all of the grammatical principles of a language, possess a large vocabulary in that language, but if that person has not learned the myriad ways of saying things in that language, s/he will not speak like a native speaker. In other words, such a person's utterance is likely to be unidiomatic or not in agreement with the ways native speaker say things. For example, in most Romance languages, the way to say,

"I am hungry", is literally "I have hunger." If a Spaniard says in English, "I have hunger" to mean "I am hungry", the Spaniard has not made a grammatical mistake in English. His utterance is simply unidiomatic, i.e. not in accord with the way native speakers say it!

Most polyglots have witnessed interesting and amusing examples of unidiomatic utterances by non-native speakers. The important point is that the ways of saying things tend to be unique to a language or a group of closely related languages, and they are not confined to a few special expressions.

The New Zealand linguist, Andrew Pawley, has written eloquently about this aspect of language. So has his teacher, the American linguist, George Grace (1987). I will quote from an article by Pawley (1991),

A language can be viewed as being (among other things) a code for saying things. There are a number of conventions that constrain how things should be said in a language generally or in particular contexts. Here I will mention only the general maxim: *be idiomatic*. This means, roughly, that the speaker (author, translator, etc.) should express the idea in terms that native speakers are accustomed to. For example, if you ask me the time and my watch shows the little hand pointing just past the 5 and the big hand pointing to the 2, an idiomatic answer would be 'It's ten past five', or 'It's five ten'. A reply such as 'It's five o'clock and one sixth' or 'It's five-sixth of an hour to six' or 'It's six less than fifty' would not count as idiomatic. To break the idiomaticity convention is to speak unnaturally. (Pawley 1991: 433)

The implication of this important characteristic of language is that linguistic behavior requires a prodigious memory. The neocortex of our brain must be able to store a vast amount of knowledge acquired through learning: the vocabulary, the grammar, and the myriad ways of saying things. We wish to emphasize that this knowledge is acquired through learning. We may be genetically predisposed toward acquiring language ontologically. Since language is our species-specific communicative behavior, there is nothing unusual for humans to be genetically predisposed toward acquiring language. Every species in the animal kingdom is either genetically programmed or predisposed to develop its species-specific communicative behavior. Earlier discussion points out that vocal production in non-human primates is largely innate, although vocal usage and proper communicative response to conspecifics require some learning. Acquisition of the first casual spoken language by children, however, requires a great deal of learning and a long, arduous process in comparison with the ontological development of the communicative behavior among non-human primates.¹³ The human predisposition toward acquiring a casual spoken language does not imply an innate template of language-specific principles and parameters as Chomsky (1986) and Pinker (1994) claim.¹⁴ What is innate, in our opinion, is the architectural and chronotopic development

of the human brain in ontogeny, which channels the human infant's attention to the linguistic and social interaction of his/her environment and enables the human infant to learn a complex symbolic behavior requiring, among other things, a prodigious memory. The acquisition of language is, then, a complex interplay between this innate predisposition and the language environment (Elman, Bates et al. 1996; Elman 1999). From his/her linguistic environment, a child learns the vocabulary, the grammar and the myriad ways of saying things in a language. Having a large neocortex for our physical size constitutes an important aspect of the genetic predisposition toward acquiring a language. But human beings are not innately endowed with any knowledge of how to say things in any language. The numerous ways of saying things in a language require a long process of learning and tremendous amount of memorizing beyond the vocabulary and the grammar.¹⁵

Since language requires a large cognitive memory because of the vocabulary and the myriad ways of saying things, the expansion of the neocortex in hominid evolution must be co-related with the origin of language.

We should point out that in spite of the fact that increase in encephalization has received the most attention in the research on the origin of language, the other three evolutionary processes, namely, the decrease of the gastrointestinal tract, the increase of the vertebral canal and the descent of the larynx, are equally important.

We have summarized the four evolutionary processes that accompanied the development of hominid communicative behavior. We will now briefly delve into the three underlying evolutionary mechanisms.

5. Three evolutionary mechanisms underlying the emergence of language

5.1 Duplication of Homeotic genes

The mechanism underlying the sudden origin of phenotypic characteristics whether anatomical, physiological or behavioral is the duplication of the master regulatory genes, the so-called Homeotic genes.

Sudden origin of phenotypic features complements the classical Darwinian evolutionary change, which tends to be gradual and incremental. But sudden origin is also Darwinian. What is unusual about it is the nature of underlying genetic change, namely the duplication of the master regulatory genes, the homeotic genes.

Homeotic genes specify the synthesis of Transcription Factors, which turn on or off structural genes in a developing embryo. Turning on or off structural genes will determine the synthesis of certain enzymes and the growth or the absence of growth of specific physical structures. A minor illustration of a change in these master regulatory genes in human beings is the growth of six fingers on one hand.

A major illustration would be the development of an otherwise normal embryo without a head, due to the deletion of one such master regulatory gene, called LIM-1.

Most of the human homeotic genes turn out to be products of gene duplications at different times in evolution. Gene duplication as an evolutionary innovation has two distinct advantages. First, gene duplication can accomplish in one swoop what may have taken eons of time to create through the cumulative effect of gradual and piecemeal evolutionary changes in each of the original genes. Secondly, when a master regulatory gene is duplicated, the duplicated gene may undergo mutations, and therefore, perform new functions, because the original gene continues to perform its old functions that are necessary for the survival of the organism.¹⁶ If the new functions are favored by natural selection, we obtain a sudden origin of new phenotypic manifestation and possibly a new species. The consequence of duplicating the genes regulating structural development is that the resulting structures should also show signs of duplication. However, the duplicated structures will be modified if the duplicated genes have undergone mutation. An obvious example of repeated structures in humans are the vertebrate column. The brain also contains many repeated structures, for example, the radial units of the embryo in its early stage of development, which are ultimately responsible for the size and architectonic pattern of the neocortex (Rakic 1988). These repeated structures could have arisen phylogenetically from the duplication of regulatory genes.

Recently, it has been discovered that genes which regulate the formation of the neocortex of the mammalian brain, known as *Emx-1* and *Emx-2*, are duplicated and mutated copies of the genes that control head and brain formation in fruit flies. So the most advanced portion of my brain goes back to a very humble origin (Allman 1999)!

We wish to make clear that the sudden origin of phenotypic characteristics does not imply any suggestion of the sudden origin of language. On the contrary, by our reckoning, it took approximately 1.5–2 million years for hominid communicative behavior to evolve into casual spoken language. The relevance of the mechanism for the sudden origin of phenotypic characteristics to the origin of language lies in the development of the brain in hominid history. Aside from our earlier speculation of the evolutionary increase of radial units based on Rakic's research, Allman (1999) also suggests that many areas of the neocortex could have arisen in evolution from duplications of pre-existing areas as a result of genetic mutation. This evolutionary mechanism de-mystifies the dramatic expansion of the hominid brain during the past two and half million years, a relatively short duration on the evolutionary scale of time.

5.2 Change of the developmental clock

The second evolutionary mechanism concerns the change of the developmental clock. Developmental clock designates the length of ontological development of an animal or an organ of an animal.

The molecular mechanism determining the length of the molecular clock, however, is complex, involving regulatory genes as well as a feedback system consisting of inter-cellular communication. This evolutionary mechanism is important to the origin of language. Human language, as we all know, is inextricably connected with our large brain. One reason for the proportional large brain in *Homo sapiens* vis-a-vis the great apes, for example, is that the developmental clock for the human brain is lengthened considerably. The brain size of a human infant is not very much larger than that of an infant chimpanzee. But the human infant brain continues its developmental path for nearly twenty years. A chimp brain stops expansion three months after birth.¹⁷

While the lengthening of the developmental clock for the brain is partly responsible for the increase in encephalization among hominids, slowing down the developmental clock of the body also plays a role in creating a large human brain in proportion to body size. Slowing down the developmental clock for the body means terminating the developmental process long before the human body can reach a stage and size commensurate with the brain. This result is known as the *decrease in somatization*. An example of the slowing down of the human developmental clock is the late eruption of human teeth. In apes, for example, the deciduous teeth come out soon after birth. In human infants, the deciduous teeth continue to erupt well into the second year. In apes, the molars erupt immediately after deciduous teeth come out. In humans, the third molars, the so-called wisdom teeth, do not erupt until either late teens or early twenties.

Even though molecular biologists have not yet elucidated the full picture of how developmental clock is determined, we know that a change in developmental clock does not necessarily require long term, cumulative genetic mutations. In other words, the change of developmental clock for the body and the brain in hominids could occur suddenly. These changes in part explain the relatively large number of hominid species during the five million years before the emergence of anatomically modern humans.

5.3 The causal role of behavior in evolution

The third evolutionary mechanism is the causal role of behavior in evolution. This is an evolutionary mechanism that tends to be overlooked in contemporary, genetically based theory of evolution. James Mark Baldwin (1896) was the first evolutionary theorist to suggest that the behavior of animals can influence the course and

the direction of the evolution of their own species. By now we know that among vertebrates, the penetration of a new habitat, for example, is typically initiated by behavior rather than genetic mutation. The best known cases are the Darwinian finches of the Galapagos islands. A new habitat will unleash a new set of forces of natural selection operating on the animal and move the animal into a new direction of evolution.

Ernst Mayr (1963) took up Baldwin's theory and wrote, "a shift into a new niche or adaptive zone is, almost without exception, initiated by a change in behavior. . . . the importance of behavior in initiating new evolutionary events is self-evident" (p. 604). More recently, Plotkin (1988) provides a collection of insightful articles on the role of behavior in evolution. In particular, Plotkin observed that social learning directly impinged upon the biological evolution of hominids and hominoids. Social learning, of course, is the process through which innovative behavior can pass from the innovator to its social cohorts and onto the next generation. Social learning is also critical in first language acquisition. Decades ago, the emphasis in research on first language acquisition was the creative aspect of children's language acquisitional process. Empirical studies in the last twenty years have demonstrated that while there is definitely a creative aspect in children's acquisition of language, social learning and imitation are extremely important. In the evolutionary development of hominids, the speed and capacity of social learning and imitation expanded dramatically. The expansion has a neurological base in the increase in encephalization. More specifically, the increase of mirror neurons in the neocortex plays a significant role in the expansion of hominids' capacity of learning and imitation.¹⁸ Mirror neurons are found in many areas of the neocortex including the Broca's area. Since they are responsible for both production and perception, any increase in the number of mirror neurons in the association neocortex will enhance the ability of learning and imitation. We assume that the increase in the number of mirror neurons in hominid evolution is proportional to the increase in encephalization.

6. A humble beginning of symbolic communication

A variety of evidence from linguistics, psychology and child language suggests that representing some concrete object with a communicative signal is the least cognitively demanding of all symbolic communicative behavior. For this reason, we submit that the first step in the co-evolution of hominid brain and hominid communicative behavior is the naming of a concrete object.

Symbolic behavior, as we all know, has tremendous adaptive value. Just being able to name even one concrete object, such as a predator or a prey or a food item,

would confer a significant competitive edge to a group of hominids. Suppose an early hominid, for example, a *Homo erectus*, in a flash of creative innovation, first invented one communicative signal symbolizing some concrete object, his or her social group would be able to learn such symbolic communicative signal from the innovator. As a consequence, this group of *Homo erectus* would have a competitive edge for survival and reproduction over other hominids. We assume that before the occurrence of the first symbolic communicative signal, the communicative behavior of hominids was not significantly different from the design of contemporary non-human primate communication. In particular, such an assumption implies that like non-human primates, early hominids communicative signals have functions only but not meaning. The genius of inventing the first symbolic signal lies in switching from the mid-brain to the neocortex as the primary neural substrate for signal production. This is why the invention of the first symbolic communicative signal is such an important innovation. At the time of the innovation, the part of the neocortex being hijacked for mediating the production of the first few symbolic communicative signals could be the Broca-Wernicke region of the association neocortex, which probably directed certain motor behavior in response to auditory input. This first innovation then sets the stage for the co-evolution of communicative behavior, brain, culture, size of social group and other anatomical innovations. The advantage of postulating behavior rather than genetic mutation initiating the co-evolutionary process should be obvious. New communicative behavior can be passed on to other members of a social group and to future generations through learning and imitation. If the initial symbolic communicative behavior had to be engendered by a genetic mutation, then those who did not undergo such a genetic mutation would not and could not have the behavior. It is highly improbable that an entire social group of hominids all underwent the same genetic mutation at the same time. If only one hominid underwent such a mutation, this hominid would stand out as a freak among its peers since no one else could produce or understand its new communicative behavior. In such a case, even without taking into consideration the normal effect of genetic drift, it would be highly improbable that such a genetic trait resulting from mutation could spread and thrive. A social freak among a group of hominids or any other animals would have a slim chance to survive. Ostracization would be its immediate fate.

Given the scenario in which a hominid of the genus *Homo*, in a flash of creative innovation, invented a linguistic sign, some questions immediately jump to mind: How realistic is such a scenario? Is it just wishful thinking or is there some evidence for it? Wouldn't symbolic communicative behavior, even at the most elementary level of having one or two symbols for some concrete objects, require a qualitatively different brain? The questions are interrelated. The fundamental issue hinges on whether or not simple symbolic communicative behavior requires a brain with a

language module. We believe that it does not. Instead of postulating a language module in my brain, we would like to introduce the concept of *cognitive reserve*.

7. Cognitive reserve

By cognitive reserve, we mean cognitive capability that is not fully utilized or manifested in the normal repertoire of behavior of a mammal. The various projects training great apes to manipulate linguistic symbols are evidence for the apes' cognitive reserve specifically in the domain of symbolic communication. Regardless of the controversy surrounding the degree of success of these projects involving the chimps Sarah and Washo, the bonobo Kanzi, the gorilla Koko, there is no doubt that these great apes are able to acquire and use some linguistic signs after extensive and intensive training. It is true that in their natural environment, apes' communication is strictly non-symbolic and they give no indication of developing symbolic communication. It is only through human intervention that they succeed in acquiring some linguistic symbols. The important point is that they have the cognitive reserve for acquiring and using some linguistic symbols even if the process of acquisition is highly unnatural. We know many mammals can be trained by humans to perform a great variety of impressive cognitive feats that are not included in their natural behavioral repertoire. Much of the trained behavior is evidence in support of what we call the mammal's cognitive reserve. It exists in all mammals endowed with a neocortex: the ability to perform some novel behavior that is not expected in its normal repertoire. It probably exists in other animals to a lesser extent.

From an evolutionary perspective, the existence of cognitive reserve is not at all surprising. In fact, it is expected. Evolution does not create a central nervous system without any reserve for unexpected demands or unexpected change of environmental or ecological conditions. Mammals without such reserve capacity are unlikely to survive very long in a changing world, and the world is always changing and never short of the unexpected.

The evidence for cognitive reserve, however, extends beyond the success of human effort to train great apes to acquire linguistic symbols. There are cases of mammalian behavior in their natural environment that suggest a level of cognitive capability which far exceeds what is manifested in their usual behavioral repertoire. The Japanese macaque on Kojima island which acquired the methods of cleaning sand-covered potatoes and effectively sorting grain from sand is one of the best known examples. The first discovery of using a stone/wood hammer and a suitable base as an anvil for cracking nuts by the chimps in Tai forest or the first discovery

of fashioning a twig/straw into a probe for fishing out termites by the chimps of Gombe are also strokes of genius that attest to the existence of cognitive reserve.

The importance of the concept of cognitive reserve and the earlier discussion of behavior initiating a new direction of evolution is that they provide the theoretical underpinning for postulating that the dawn of symbolic communication was initiated behaviorally by a hominid in the genus *Homo*. In particular, this behavior is the creation of a communicative signal referring to a concrete object. This signal, because of its adaptive value, was transmitted through social learning to the social cohorts of that hominid and then to the next generation. Thus began a new direction of evolutionary development of the hominids: the co-evolution of brain, symbolic communicative behavior, decrease of the gastro-intestinal tract, increase of the vertebral canal, descent of the larynx and the enhancement of material culture. The various components of this co-evolutionary process are mutually reinforcing, like an arm race, one egging on the others.

8. Spoken vs. written language

It took approximately 1.5–2 million years for hominid communication to evolve into full-fledged language as I know it nowadays. 'Full-fledged language' designates casual spoken language. It is not written language, which differs *significantly* from casual spoken language in terms of vocabulary, grammar as well as coherence and organization. Contrary to the common belief, written language is not just spoken language written down. Written language is a recent cultural invention with approximately 5000 years of history, representing a crowning cultural achievement and a critical cultural instrument of great importance. But it is an inappropriate base for inferring the structure and properties of language at its point of origin. When hominid communicative behavior evolved into language, it is a spoken form of communicative vehicle for social interaction involving more than one participant. It is not a written language. If we infer the properties of language at its point of origin from contemporary casual spoken language, we will be free from the burden of figuring out how hominids gradually evolved a communicative behavior characterized by the logicity, an extremely high level of coherence and a tightly structured organization in written language. In other words, the evolution of hominid communicative behavior into casual spoken language is a stage of evolution that is completely distinct from the evolution of casual spoken language into written language in terms of chronology, process and content. The first stage is a biological evolution within the Darwinian framework. The second stage is a cultural development that has nothing to do with the Darwinian notions of natural selection and random mutation. Even though linguists are perfectly aware of

the difference between casual spoken language and written language, few take the trouble of extracting data from carefully transcribed casual conversation out of the academic setting. For many, linguistic data is obtained through introspection of how they think they utter a sentence in their own native language. Such a sentence is, at best, a token of the formal written language rather than casual spoken language for many reasons of which the most important one is that such a sentence is independent of any communicative context. The entire communicative context, linguistic or non-linguistic, visual, auditory or tactile, of any casual conversation serves as such a rich source of information to the interlocutors that renders the grammar, the diction and the organization of casual speech significantly different from those of written language.

9. Toward the crystallization of language

The first stage of the evolutionary development toward casual spoken language is the increase of communicative symbols for concrete objects, e.g. food, predator, objects for landmark, different animals, different plants. During this stage, the creation of each new symbol represents a stroke of genius by a hominid, and the establishment of each newly created symbol in the repertoire of the communicative signals of the social group to which the creator belongs, requires social and cultural transmission. The social group most likely consists of close kin in the beginning before it extends to a more distantly related clan. It is important to realize that the entire process is an evolutionary event. It did not happen every day. It did not happen every year, and it probably did not happen in every generation. We must avoid unconsciously projecting our frame of mind onto the evolutionary scene involving our hominid ancestors. They had neither the cognitive capability nor the cultural environment we have. They were at the beginning of a long evolutionary path that ultimately led to the emergence of language. They did not have language yet. We believe that the onset of symbolic communication began with *Homo erectus*. There are several reasons for our belief: (a) The *Homo erectus* brain at 800–950 cc is considerably larger than the brain of all earlier hominids, including *Homo habilis*, the first species of the *Homo* genus. (b) The *Homo erectus* brain shows an increase in cerebral asymmetries. (c) They are the first hominids which migrated out of Africa and reached as far as Asia and Indonesia evidenced by the famous fossils of Peking man and Java man. The migration suggests an expanding population, which in turn, suggests a higher level of fitness, probably caused by improved communicative capability. (d) As Holloway (1995) points out, since the time of the *Homo erectus*, the evolution of the hominid brain showed a gradual increase in volume, refinement and asymmetries that could not be allometrically

related. In other words, the *Homo erectus* brain evolved exclusively for the purpose of greater cognitive capacity. We believe that this evolutionary process of the brain is correlated with the gradual evolution of the symbolic communicative behavior.

Having a few communicative symbols for concrete objects, however, is *not tantamount* to being aware of the abstract principle of associating symbolic communicative behavior with concrete objects, even though the symbol itself is a token of this principle. In other words, there is a significant difference between using a communicative symbol for a concrete object and being aware of the principle underlying that act of creation. The various projects training apes to manipulate human linguistic symbols illustrate this difference. Sarah, Washoe, Kanzi and Koko may be able to master a good number of linguistic symbols. But there is no indication that they are aware of the underlying principle of association between a sign and what it signifies. Thus, the appearance of communicative signals that signify concrete objects 1.5–2 million years ago did not imply the dawn of language. As we have stated earlier, the addition of each new communicative signal that symbolizes another concrete object is a significant step along the evolutionary pathway toward the emergence of language. Each evolutionary step occurs on the evolutionary scale of time. There isn't a rapid cascade of new linguistic symbols following the initial appearance of a linguistic symbol in the communicative repertoire of some *Homo erectus*. Furthermore the use of each linguistic symbol was transmitted socially. That transmission process also took time. The case of the Japanese macaques on Kojima island provides some hint on the speed of transmission during the early phase of the evolution of hominid communicative behavior toward language. After the female genius macaque innovated the behavior of washing sand-covered potatoes in sea water, it took four years for the behavior to spread among eight members of the troop, all of whom happened to be the immediate kin of the female innovator. The slow pace of cultural transmission is also observed in chimpanzees learning of nut-cracking in the wild. It takes a young chimp five to six years to fully master the art of cracking nuts, sometimes with the help of its mother (Gibson & Ingold 1993). Close social tie obviously facilitated the learning of a new behavior. Learning, nevertheless, was far from being instantaneous. In contrast, anatomically modern humans learn simple skills and acquire new behaviors with nearly lightning speed. As we mentioned earlier, our speed of learning is probably facilitated by the larger number of mirror neurons we have.

Regarding the creation of communicative symbols for concrete objects, each act of creation typically involved serendipity in a highly motivating and possibly stressful situation. Besides the act of creative innovation, the expansion of linguistic symbols co-evolved with the increase in encephalization, enhancement of culture, growth in the size of social group and population, and at various points in time significant anatomical innovations. Increase in encephalization was necessary because of the demand of greater cognitive capacity and memory for handling

communicative symbols, and because the increase of mirror neurons improved the speed and capacity for learning.¹⁹ Enhancement of culture was necessary because it facilitated the spread of newly created linguistic symbol. Growth of the size of social group and population was necessary because the more hominids acquired linguistic communicative symbols, the more likely a new genius would emerge to create an additional linguistic symbol for another concrete objects. The anatomical innovations as we have already pointed out, also involve the decrease of the G.I. tract, the expansion of the thoracic nerves, the decrease in somatization and the descent of the larynx. These changes emerged through a co-evolutionary process. They did not occur in a few generations. On the one hand, the development of hominid communication toward language needed this multifaceted co-evolutionary process; on the other hand, the development of hominid communication in the direction of language, because of its adaptive value, pushed our hominid ancestors down the evolutionary path which led to these multifaceted innovations. The end product of this complex co-evolution that went on for approximately 1.5–2 million years is language. However, the pace of the development was not constant. For most of the two million years, the development was characterized by stasis. The increase of the number of linguistic symbols moved at a snail's pace. Toward the end of the two million years, i.e. around the time of the emergence of anatomically modern humans, the rate of development began to accelerate. If we plot the 1.5–2 million years of evolutionary development as a curve with the vertical axis representing the rate of change of hominid communicative behavior toward language and the horizontal axis representing time, the shape of the curve will be very similar to the curves showing the increase of hominid population and the development of stone tools. The first segment of the curve is a line with a very gentle slope characterizing primarily stasis for most of the 1.2–2 million years. The second segment of the curve is a sharp turn into a steep climb characterizing a dramatically fast approach toward language during the final 100–150 thousand years. The sharp turn signals that a critical number of linguistic symbols has been reached, and the symbols began to expand from designating concrete objects to actions, activities, events, experience, thought. At this juncture, the concatenation of linguistic symbols became a naturally emerging phenomenon. For instance, when a hominid's vocabulary was large enough to include items denoting action or activity, it would follow that the hominid understood the relation between an actor and an action or an agent and an activity. The concatenation of an actor with an action would emerge naturally.

Expressing an actor or agent with an activity suggests the incipience of grammar in the sense that there is a concatenation of words to form a larger communicative signal. When there is concatenation, there is, at the minimum, the syntactic phenomenon of word order. But syntax in the sense of word order does not require any quantum cognitive leap. As we have already pointed out, the notion of

activity or action implies the existence of an agent or an actor. If a hominid had a word for an action, we can assume that the hominid already understood that an action required an actor to execute it. As for stabilizing a word order, it is a social convention, negotiated consciously or unconsciously by the members of a community.

What about all of the other grammatical structures beyond word order found in contemporary spoken languages?

We have by now historical linguistic data that account for the emergence of nearly all grammatical conventions, be it inflection, derivation, subordination, conjunction, interrogative, imperative or subjunctive. Linguists have been able to elucidate the precise processes and mechanisms by which such grammatical constructs may emerge in a language. Grammaticalization is one of the most important mechanisms in the emergence of grammar (Traugott & Heine 1991). Grammaticalization began to occur as the hominids started to link symbolic signals into larger communicative units.

What about the notion of generating sentences that is the foundation of generative grammar?

In our discussion of the defining characteristics of language at its crystallization, we did not mention recursive function or generativity. Yet ever since Chomsky's famous publication of "Syntactic Structures", many scholars including most linguists consider recursive function the unique defining feature of human language, e.g. Pinker (1995). Indeed, if one surveys the literature on language, one cannot fail to notice the omnipresence of the concept of recursive function or generativity. It depicts the speaker's ability to generate an indefinitely large number of sentences from a finite vocabulary with a finite set of syntactic rules. Let us briefly examine recursive function and generativity.

In elementary formal logic, one of the concerns is the device needed for producing strings of symbols. The simplest device can be expressed in what is called 're-writing rule'. A re-writing rule is a rule which re-writes one symbol into a sequence of symbols. A trivial example of re-writing rule has the following form:

$$S \rightarrow aaa$$

This rule states that the symbol on the left of the arrow, 'S', is to be 're-written' as the sequence on the right of the arrow, 'aaa'. In an artificial language for computers, I can specify that the symbol 'S' designates a sentence, and according to this re-writing rule, a sentence in this formal language is represented by a string of three 'a's.

Now suppose in an artificial language we have two re-writing rules which can be applied repeatedly:

$$\begin{aligned} S &\rightarrow a \\ S &\rightarrow aS \end{aligned}$$

If we apply the first rule, we obtain a sentence consisting of one 'a'. If we apply the second rule and then apply the first rule to the output of the second rule, which is 'aS', we obtain a string of two 'a's, namely, 'aa'. If we apply the second rule twice, the first round we get 'aS', the second round we obtain 'aaS' (the output of applying the second rule to the 'S' of 'aS'). Take the result 'aaS' and now apply the first rule to the 'S'; we have 'aaa', a string of three 'a's. It should be obvious now that we can obtain as long a string of 'a's as we wish simply by applying the second rule a sufficient number of rounds.

Let's assume that in our artificial language, there is only one vocabulary item, namely, the letter 'a', and let's further assume that the sentences in this artificial language are composed of a string of 'a's. With these two rules, we can generate an infinite set of sentences in this artificial language, each of which consists of a different number of the 'a's:

The property that the second rule, $S \rightarrow aS$, has is called 'resursiveness'. Such a rule is called a 'recursive rule' because the symbol on the left of the re-writing rule recurs on the right. In natural languages, embedding and conjunction are grammatical devices that have this recursive property if one wishes to express grammatical rules in the form of re-writing rules, e.g.

$$S \rightarrow S \text{ and } S$$

This rule states that a sentence in English, 'S', can be re-written as two conjoined sentences with the grammatical word, 'and', performing the role of conjunction. Theoretically one can keep on conjoining sentences, or keep on embedding sentences so that the final product can be indefinitely long. The notion of 'generating sentences' is based on the concept of re-writing rule in logic.

If you can have indefinitely long sentences, you will have an indefinitely large number of sentences. The key notion is infinity conveyed by the expression 'indefinitely long' and 'indefinitely large'. Because there is an infinite or indefinitely large number of integers, 1, 2, 3, 4, 5, ..., no one can claim to have the largest integer. We can talk about the set of all integers. But it is an infinite or indefinitely large set!²⁰

Theoretically the number of possible sentences in English is indefinitely large because theoretically 'the longest English sentence' does not exist. If one chooses to describe English syntax or certain aspect of English syntax in terms of re-writing rules, one can claim that a recursive function is needed. However, one never conjoins or embeds an indefinitely large number of sentences in either spoken or

written language. "Indefinitely large number of sentences" or "indefinitely long sentences" are *theoretical* possibilities. In order to understand whether or not recursive property is a unique defining feature of human language, we must find out if there is a *theoretical* possibility of describing animal communicative behavior with recursive function.

Consider the songs of the humpback whales (Payne 1995). A male humpback whale song is composed of units impressionistically described as grunt, moan and squeak, which combine to form 'phrases'. Phrases are in turn combined into 'themes'. A song is made of a sequence of themes. We do not know if a phrase or a theme serves as a functional unit conveying some message. We do know that the song as a whole has a definite communicative function. It advertises to the females an individual male's presence and physical fitness for mating. In the study of animal communication, the song is called a courtship signal. The song may also serve to fend off competing males and convey territoriality during the mating season. For our purpose, the most important aspect of the humpback whale song is that it is usually sung in repetition, sometimes exceeding half an hour of time. The repetition indicates a gradation of the intensity of the signaler's emotional state. The more the repetition, the greater the desire of the male to attract the female and the more it demonstrates the male's physical fitness. Hence, repetition is not communicatively redundant. It has communicative significance.

We will describe the whale song in terms of re-writing rules. Let 'S' be the symbol for the courtship signal. Let 'a' be the symbol for one song. In order to account for the entirety of the courtship signals of the humpback whale, we need the following two re-writing rules one of which is recursive:

$$\begin{aligned} S &\rightarrow a \\ S &\rightarrow aS \end{aligned}$$

Just like our earlier example of an artificial language composed of strings of 'a', we obtain an infinite set of possible humpback whale courtship signals, each of which represents a point along the continuum of the male's emotional state and his physical fitness. This infinite set is represented by the set of strings of 'a's. Each string denotes one bout of singing which may contain any number of repetitions of the song: 'a', 'aa', 'aaa', 'aaaa', ...

Of course, no whale sings indefinitely. Such a fact, however, is no more or no less meritorious than the fact that no human being conjoins or embeds sentences indefinitely! The issue here is theoretical capability. In real life, humpback whales often sing continuously for half an hour or more. It is difficult to think of a human being taking half an hour to utter one sentence.

One can also argue that the singing of some song birds have the recursive property. Most song birds repeat their songs as the humpback whale does. One only needs a sleepless night in the spring time and listen to the mocking bird which of-

ten sings continuously for several hours. The stronger and healthier the bird, the more repetitions it sings during the mating season, and each repetition signals a higher notch of intensity and therefore, the physical fitness and the motivation of the male singer.

In conclusion, the generative hypothesis of human language does not seem to serve any purpose. It has diverted the attention of scholars toward artificial problems that have little or no bearing on the nature of language. One could argue that there is a potential to represent some aspects of a language with a recursive function. But as we have pointed out, there is also a potential to represent some animal communicative signals with a recursive function. In short, recursive function is not a property uniquely attributable to human language. The important characteristics of language related to recursiveness is the creativity demonstrated by native speakers. Creativity in language use, however, is primarily based on the principle of analogy. There is no need to use the recursive function to account for linguistic ingenuity. Analogy provides the mechanism for creating new expressions and utterances. Metaphors and the ways we say things are two of the most important bases for the creation of new utterances through analogy. Both metaphors and the ways we say things are two of the most critical components of language.

Since the 1960's, most linguists have accepted Chomsky's idea that linguistic data for syntactic-semantic research is best obtained by the linguist through introspection of his/her own native language. However, academics spend a lifetime reading and learning to write and speak in the academic style. When they use themselves as a source of data, naturally the data that wells up in their mind are isolated sentences from their academic, written language.

When Chomsky and generative linguists talk about the ease with which a child acquires fluency in a native language within two years in early childhood, they are talking about casual, spontaneous spoken language. But when they describe the syntactic structures of language on the basis of introspected data, they are describing tokens of academic, written language. We have already noted that the difference between casual, spoken language and academic written language is enormous. There is an even greater difference between the acquisition of the first spoken language and the acquisition of literacy. Learning to write has none of the spontaneity and ease that characterizes the acquisition of the first spoken language. All human infants, with some rare exceptions due to deformity, are destined to acquire a spoken language. Not all humans are destined to acquire literacy. Learning to write requires education, assistance, guidance and years, if not decades, of practice. There is as much gradation in the quality of written language as there are educated people in a society. In short, written language is a codified cultural artifact for the purpose of creating records without the same kind of situational and contextual information and without prosody, facial expression, body posture and physical contact, all

of which are available in speech interaction. Written language is not the result of biological evolution. As we have pointed out, it is a cultural product.

Finally we wish to point out that much of what generative linguists consider as canonical grammatical constructions are formalized or conventionalized in written language. Since most linguists speak or try to speak in the style they write, the canonical grammatical constructions are transported into their spoken language. They may believe that such grammatical constructions are the mental prototypes of the language, and the data of casual spoken language represent what Chomsky (1965) calls the "degenerate" data that are fragments of the full forms. This belief is further reinforced by the fact that formal written language carries greater social prestige than casual spoken language because of the written genre's associations with literacy, education and social status. Thus, the perception that the canonical grammatical constructions of formal, written language are the mental prototypes of language is based on a social prescription enforced through education, literacy and value system. From the perspective of evolution, language is first and foremost a human communicative behavior. If we are to study the human communicative behavior, we must base our study on casual, spoken language transcribed with the utmost fidelity and not viewed as fragments of stylistic conventions. Casual spoken language does not have the grammar of formal written language. In a forthcoming article, Paul Hopper, after describing and analyzing data on several syntactic constructions from a spoken English corpus, concluded,

Corpus studies suggest that the "degenerate" data are the true substance of natural spoken language, and that what my grammars give me then are normativized assemblies of these fragments that tend to impress themselves on me as mental prototypes because of their greater social prestige.

(Hopper, forthcoming)

We find it ironic that in the empirical investigation of language, which is a human behavior with an evolutionary history, it is necessary to defend the importance of authentic, unedited behavioral data collected from casual, spoken language.²¹ Obviously for many linguists, such data are fragmented and unimportant. Such an attitude has impeded the investigation of the evolutionary origin of language.

In conclusion, this paper represents a condensation of 6 million years of hominid evolution and a sketch of a diverse array of information from many disciplines that are relevant to the evolutionary origin of language. Many important topics are left out and many others receive only a brief cursory presentation. As a consequence, the paper reminds me of an old Chinese saying: "Flower appreciation on a galloping horse." For blurred images and obscure landscape, we apologize. However, it is important to note that during the past decade major contributions toward an understanding of the origin of language have come primarily from the neurosciences and paleoanthropology. We hope that we are successful in demon-

strating that linguistics can also contribute toward an understanding of the origin of language, once we move beyond the mist created by the generative paradigm.

Notes

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1. It will be clear later in this paper that the definition of language as the casual spoken language of human beings is of extreme importance. I use the term 'anatomically modern humans' to circumvent the confusion caused by a proliferation of taxonomic terms such as Early Homo sapiens, Archaic Homo sapiens, Homo sapien sapiens, etc. Compared to the hominids of the past 250,000 years, anatomically modern humans have a gracile skeleton characterized by long bone shape, a specific depth and extent of muscle insertion, a thin cranial wall and mandibular body, a high, domed cranium, a reduced jaw, and the absence of a prominent browridge over the eyebrow, i.e. no supraorbital torus.
2. For a succinct and comprehensive analysis of the current hominin taxonomy, see Wood and Collard (1999). A new discovery, however, poses additional challenge to the already controversial hominin taxonomy. On December 4, 2000, French and Kenyan paleoanthropologists announced the discovery of "Millennium Ancestor" (*Orrorin tugeensis*) in the Tugen hills of Kenya's Baringo district in the Great Rift Valley. The fossil remains include various body parts belonging to five individuals. The fossils have not been dated yet. But the strata where the fossils lay buried show an age of 6 million years. If the dating proves correct, these fossils would be approximately 1.5–2 million years older than the *Ardipithecus*. They would yield exciting information of the earliest evolutionary development of hominids. Preliminary report suggests that the Millennium Ancestor was about the size of a modern chimpanzee and capable of walking upright as well as tree-climbing. The discoverers of the Millennium Ancestor, Brigitte Senut and Martin Pickford, hypothesize that all Australopithecines belong to a side branch of the hominid family tree, and the Millennium Ancestor, not Lucy, the *Australopithecus afarensis*, is the direct ancestor of modern humans. They base their hypothesis on three key factors: (1) the age of the fossils at 6 million year. (2) The *Orrorin's* femurs which point to some level of bipedalism. (3) The molars of the *Orrorin* which are small, squared and thickly enameled. These features of the molars remain with anatomically modern humans.
3. The evolution of bipedalism took several million years to complete. It involved the change of the skeleton from the skull to the toe, the redesign of the nervous system and the change of muscular structure from the neck down. Even though Lucy, the famous *Australopithecus afarensis* who lived more than 3 million years ago, was a fully functional bipedal hominid, the changes involved in bipedalism did not complete until the emergence of the *Homo erectus*.

4. Non-human primate communicative signals are typically multi-modal, involving visual as well as auditory, and sometimes tactile channels. But their visual (such as facial expression, body postures) and tactile communicative signals are even more transparent as manifestations of their emotional and motivational states.
5. The deceptive use of communicative signals among primates, which has been observed among several species, would involve cognition beyond the involuntary vocalization stimulated by an external circumstance. Deception, however, is not frequently observed among primates, even though it suggests that the use of a communicative signal for deception is subverted by the neo-cortex.
6. There is an amusing incidence involving a chimp discovering a cache of delectable food at Jane Goodall's camp in Gombe. It immediately went behind a tree and covered its mouth so that its involuntary food call cannot be heard and its facial expression of excitement cannot be seen by its companions. This episode is significant because it demonstrates that (1) the chimp is aware of its own emotional reaction to the sudden discovery of delectable food, and (2) through its neocortex, it is trying to conceal its emotional states expressed by its communicative signals. Similar incidences involving other primates have been reported by ethologists, for example, Cheney and Seyfarth's (1990) account of deception by vervet monkeys.
7. The change of some animal communicative signals may be culturally transmitted, e.g. the courtship songs of the white-crowned sparrow are known to have dialectal differences. In such cases of the change of animal communicative behavior, the classical Darwinian evolutionary process does not apply and the time of change may be very short.
8. If language crystallized several tens of thousands of years after the emergence of anatomically modern humans, the polygenesis of language would be possible. The issue of monogenesis vs. polygenesis of language is briefly discussed in Li (2002, 2003).
9. The m-DNA contains only 37 genes and 16569 base pairs. The small number of genes and base pairs make it easy to examine the variability of m-DNA in different individuals. Most important of all, mitochondrial genes are maternally transmitted, although recent investigations show that rare leakage of paternal m-DNA into a fertilized ovum is possible. If the source of m-DNA is exclusively maternal, then variation of the m-DNA can only be caused by mutation. Thus a molecular clock based on an average mutation rate in the m-DNA tends to be reliable. For an informative discussion of the mitochondrial DNA and its relevance to human evolution, see Cann (1995).
10. Before Tim White unearthed the fossils of *Australopithecus Ghari* in Ethiopia in 1997, the Oldowan in Kenya is the oldest known stone tool technology. The Oldowan tools date from 2.5 to 1.7 million years ago, and they are associated with the emergence of the genus *Homo*. However, *Australopithecus Ghari*, which is dated 2.5 million years ago, used stone tools which were carried from a site more than 50 miles away from the location of the Ghari fossils. This discovery nullified the long-standing belief that stone tools were a *Homo* invention. The Acheulian technology emerged with the *Homo erectus*. The major difference between the Oldowan and the Acheulian is the addition of the hand ax, the cleaver and the pick in the Acheulian technology. The Mousterian technology contained a larger range of tool types than the Acheulian. However, the Mousterian technology, associated with the Neanderthals, did not exhibit much technological improvement over the Acheulian.

11. For an informative discussion of the evolution of the human brain and a comparison of the human brain with animal brains, see Falk (1991) and Roth (2000).
12. Some animals have a better memory for certain sensory experience than humans. For example, dogs and cats are better than humans in remembering olfactory experience. This fact, however, does not imply that dogs and cats have a larger capacity for cognitive memory. Their olfactory perception is much more acute than that of human beings. Their greater ability to perceive and differentiate odors is connected to their better olfactory memory.
13. For a succinct summary of children's acquisition of grammar, see Bates and Goodman (1999).
14. We take note of the fact that Chomsky's current theoretical stance is considerably different from his 1986 pronouncements. In his new Minimalist Program (Chomsky 1995), grammar is largely derived from the lexicon. If we are correct in assuming that what is considered innate by Chomsky and his followers is the newest version of the so-called "Universal Grammar", which is austere and minimal, the issue of representational innateness for language behavior is practically moot.
15. In some grammars, one finds some sporadic discussion of some particular ways of saying things. Typically such a grammar concerns a language unrelated to the Indo-European language family. The authors are motivated to discuss some ways of saying things in those languages because many of these ways of saying are bizarre from the Indo-European perspective. For example, in most grammars of Sub-Sahara African and East Asian languages, 'serial verb construction' is usually presented because it is a construction that does not occur in Indo-European languages.
16. A gene carries the information for coding a particular protein, and each protein plays an important role in the anatomy and physiology of an animal. Hence the mutation of a gene, by and large, is deleterious because the mutation may impair the synthesis of a particular protein which is essential for survival.
17. Although a chimp brain stops expanding three months after birth, its development including myelination and neuronal connections is not complete until approximately five years of age.
18. Mirror neurons were discovered in the laboratory of Giacomo Rizzolatti. For more information on language and mirror neurons, see Rizzolatti and Arbib (1998).
19. There is no hard evidence for the increase of mirror neurons in the evolutionary development of hominids. I do know from the work of Rizzolatti et al. (1988) that mirror neurons are phylogenetically old. In fact, the discovery of mirror neurons first occurred in experiments involving monkeys (Rizzolatti et al. 1996). My claim of the increase of mirror neurons in hominid evolution is based on the inference that as the hominid brain increased in size, the number of mirror neurons increased correspondingly.
20. Another trick connected with the notion of infinity is the correct, but seemingly counter-intuitive, fact that there are as many even integers (2, 4, 6, 8, 10 ...) as there are integers (1, 2, 3, 4, 5, ...). To prove this claim, I perform the simple operation of multiplying each integer by the number 2. This operation does not affect the number of integers. But after the operation, the set of integers becomes the set of even integers without any change in the total number of elements in the set. The reason is that 'the total number of elements

in the set' can lead to confusion. This 'total number' is no longer an integer. It is an infinity, or more precisely, a countable infinity. There are other kinds of infinities in mathematics. None of them is an integer.

21. There are by now many corpora of carefully transcribed data of casual conversations. One corpus used by me is the Santa Barbara Corpus of Spoken American English created by John Du Bois (2000).

References

- Aiello, L., & Wheeler, P. (1995). The expensive tissue hypothesis. *Current Anthropology*, 36, 199–221.
- Aitken, P. G. (1981). Cortical control of conditioned and spontaneous vocal behavior in rhesus monkeys. *Brain and Language*, 13, 636–642.
- Allman, J. M. (1999). *Evolving Brains*. New York: Scientific American Library.
- Arensburg, B. (1989). A middle Paleolithic hyoid bone. *Nature*, 338, 758–760.
- Baldwin, J. M. (1902). *Development and Evolution*. New York: Macmillan.
- Balter, M. (1999). New light on the oldest art. *Science*, 283, 920–922.
- Bates, E., & Goodman, J. C. (1999). On the emergence of grammar from the lexicon. In B. MacWhinney (Ed.), *The Emergence of Language* (pp. 29–80). Mahwah, New Jersey: Lawrence Erlbaum Publishers.
- Berger, L. (2000). *In the Footsteps of Eve*. Washington, DC: National Geographic Adventure Press.
- Biraben, J.-N. (1979). Essai sur l'évolution du nombre des Hommes. *Population*, 1, 13–25.
- Cann, R. L. (1995). Mitochondrial DNA and human evolution. In J.-P. Changeux & J. Chavillon (Eds.), *Origins of the Human Brain* (pp. 127–135). Oxford: Clarendon Press.
- Cheney, D. L., & Seyfarth, R. M. (1990). *How monkeys see the world: Inside the mind of another species*. Chicago: The University of Chicago Press.
- Chomsky, N. (1957). *Syntactic Structures*. The Hague: Mouton Publisher.
- Chomsky, N. (1965). *Aspects of a Theory of Syntax*. Cambridge, MA: MIT Press.
- Chomsky, N. (1986). *Knowledge of Language: Its nature, origin, and use*. New York: Praeger.
- Chomsky, N. (1995). *The Minimalist Program*. Cambridge, MA: MIT Press.
- Du Bois, J. (2000). *Santa Barbara Corpus of Spoken American English*. CD-ROM. Philadelphia: Linguistic Data Consortium.
- Elman, J. (1999). The emergence of language: A conspiracy theory. In B. MacWhinney (Ed.), *The Emergence of Language* (pp. 1–28). Mahwah, New Jersey: Lawrence Erlbaum Publishers.
- Elman, J., Bates, E., Johnson, M., Karmiloff-Smith, A., Parisi, D., & Plunkett, K. (1996). *Rethinking Innateness: A connectionist perspective on development*. Cambridge: MIT Press.
- Falk, D. (1991). 3.5 million years of hominid brain evolution. *The Neurosciences*, 3, 409–416.
- Gibson, K., & Ingold, T. (Eds.). (1993). *Tools, Language and Cognition in Human Evolution*. Cambridge: Cambridge University Press.

- Grace, G. (1987). *The Linguistic Construction of Reality*. New York: Croom Helm.
- Hassan, F. (1981). *Demographic Archaeology*. New York: Academic Press.
- Hockett, C. (1960). The origin of speech. *Scientific American*, 203, 88–96.
- Holloway, R. (1995). Toward a synthetic theory of human brain evolution. In J.-P. Changeux & J. Chavailleon (Eds.), *Origins of the Human Brain* (pp. 42–54). Oxford: Clarendon Press.
- Hopper, P. (forthcoming). Grammatical constructions and their discourse origins: Prototype or family resemblance? In *Proceedings of the LAUD 2000 Conference on Cognitive Linguistics*. Duisburg, Germany: LAUD.
- Johanson, D., & Edgar, B. (1996). *From Lucy to Language*. New York: Simon & Schuster.
- Klein, R. (1989). *The Human Career: Human biological and cultural origins*. Chicago: University of Chicago Press.
- Lewin, R. (1993). *The Origin of Modern Human*. New York: Scientific American Library.
- Li, C. N. (2002). Some issues in the origin of language. In J. Bybee (Ed.), *Papers in Honor of Sandra Thompson*. Amsterdam: John Benjamins, in press.
- Li, C. N. (2003). *The Evolutionary Origin of Language*. New York: Regan Books, Harper-Collins Publishers.
- MacLarnon, A., & Hewitt, G. (1999). The evolution of human speech: The role of enhanced breathing control. *American Journal of Physical Anthropology*, 109, 341–363.
- Mayr, E. (1963). *Animal Species and Evolution*. Cambridge: Harvard University Press.
- O'Connell, J. F., Hawkes, K., & Blurton Jones, N. G. (1999). Grandmothering and the evolution of *Homo erectus*. *Journal of Human Evolution*, 36(5), 461–485.
- Pandya, D. P., Seltzer, B., & Barbas, H. (1988). Input-output organization of the primate cerebral cortex. In H. Steklis & J. Erwin (Eds.), *Comparative Primate Biology: Neurosciences* (pp. 39–80). New York: Liss.
- Pawley, A. (1991). Saying things in Kalam: Reflections on language and translation. In A. Pawley (Ed.), *Man and a Half: Essays in Pacific anthropology and ethnobiology in honor of Ralph Bulmer*. Auckland: The Polynesian Society.
- Payne, R. (1995). *Among Whales*. New York: Bantam Doubleday Dell Publishing Group.
- Pinker, S. (1994). *The Language Instinct: How the mind creates language*. New York: William Morrow.
- Pinker, S. (1995). Facts about human language relevant to its evolution. In J.-P. Changeux & J. Chavailleon (Eds.), *Origin of the Brain* (pp. 262–283). Oxford: Oxford University Press.
- Plotkin, H. C. (1998). *The Role of Behavior in Evolution*. Cambridge: MIT Press.
- Rakic, P. (1988). Specification of cerebral cortical areas. *Science*, 241, 170–76.
- Rizzolatti, G., & Arbib, M. (1998). Language within my grasp. *Trends in Neuroscience*, 21, 188–194.
- Rizzolatti, G., Camarda, R., Fogassi, L., Gentilucci, M., Luppino, G., & Matelli, M. (1988). Functional organization of inferior area 6 in the macaque monkey: II. Area F5 and the control of distal movements. *Experimental Brain Research*, 71, 491–507.
- Rizzolatti, G., Fadiga, L., Gallese, V., & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research*, 3, 131–141.
- Roth, G. (2000). The evolution of consciousness. In G. Roth, & M. Wullimann (Eds.), *The Evolution of Brain and Cognition*. New York: Wiley.

- Seyfarth, R. M., & Cheney, D. L. (1999). Production, usage, and response in nonhuman primate vocal development. In M. Hauser & M. Konishi (Eds.), *The Design of Animal Communication* (pp. 391–417). Cambridge, MA: MIT Press.
- Sherry, S. T., Rogers, A. R., Harpending, H., Soodyall, H., Jenkins, T., & Stoneking, M. (1994). Mismatch distributions of m-DNA reveal recent human population expansions. *Human Biology*, 66, 761–775.
- Traugott, E., & Heine, B. (Eds.). (1991). *Approaches to Grammaticalization*, Vols. I & II. Amsterdam: John Benjamins.
- Walker, A., & Shipman, P. (1996). *The Wisdom of Bones: In search of human origins*. New York: Knopf.
- White, R. (1986). *Dark Caves, Bright Visions*. New York: The American Museum of Natural History.
- Wood, B., & Collard, M. (1999). The human genus. *Science*, 284, 65–71.
- Wrangham, R. W., Jones, J. H., Laden, G., Pilbeam, D., & Conklin-Brittain, N. (1999). The raw and the stolen: Cooking and the ecology of human origins. *Current Anthropology*, 40(5), 567–594.