

Language Evolution and Human Development

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Language is a unique hallmark of the human species. Although many species can communicate in limited ways about things that are physically present, only humans can construct a full narrative characterization of events occurring outside of the here and now. Humans are also unique in their ability to fashion tools such as arrow points, axes, traps, and clothing. By using language to control the social coordination of tool making, humans have produced a material society that has achieved domination over all the creatures of our world and often over Nature herself. The religions of the world have interpreted our unique linguistic endowment as a Special Gift bestowed directly by the Creator. Scientists have also been influenced by this view of language, often attributing the emergence of this remarkable species-specific ability to some single, pivotal salutatory event in human evolution. I will refer to this sudden evolutionary jump into true human language as linguistic saltation.

Linguistic saltationists (Bickerton, 1990; Chomsky, 1975; Hauser, Chomsky, & Fitch, 2002) tend to see language as a very recent evolutionary event. They can note that the divergence of our hominid ancestors from the Great Apes occurred over 6 million years ago. However, evidence for distinctly human activities such as art, agriculture, writing, burial, pottery, and jewelry seldom goes back further than 40,000 years. Theorists such as Mithen (1996) have suggested that the crucial evolutionary development that led to the burst in creativity in the Neolithic was the emergence of human language as a method for integrating across cognitive modules. It seems quite likely that some aspect of language evolution played a major role in the recent creativity explosion. However, it would be a mistake to think that language could emerge suddenly in all its complex phonological and syntactic glory in the last 40,000 years without having been foreshadowed by major developments during the rest of our 6 million year history. In particular, we know that 300,000 years ago there was a major expansion of the parts of the vertebrae that carry nerves for the intercostal muscles (MacLarnon & Hewitt, 1999). The intercostals are the muscles that control the pulmonic pulsing that drives human phonation. The expansion of these pathways indicates that we were developing a reliance on vocal communication as far back as 300,000 years ago. But it is also apparent that the language we produced at that time was not structured or complex enough to serve as a support for the development of material culture.

Language relies on far more physiological, social, and neural systems than just the intercostal muscles. It depends on systems for cortical control of vocalization, changes in group structure and affective relations, growth in cognitive abilities, neural pathways for information integration, and mechanisms for the formation of social hierarchies. The hominid lineage has undergone a remarkable series of physiological adaptations involving skeletal modifications to support upright posture, development of an opposing thumb, changes in the birth process (Hockett & Ascher, 1964), loss of hair (Morgan, 1997), adaptation of the gastrointestinal tract, increased innervation of the intercostal

muscles (MacLarnon & Hewitt, 1999), loss of pronounced canine teeth, bending of the vocal tract, refinement of the facial musculature, freeing of the vocal folds, and sharpening of the chin. Each of these adaptations plays a role in supporting language. Beginning about 3 MYA (million years ago) there has been a gradual tripling of brain size (Holloway, 1995) which has brought massive changes in the interconnectedness of the frontal lobes, changes in the linkage of vocal production to motor and emotional areas, linkages of the visual areas to motor areas, and expansion of many older areas, including the cerebellum, basal ganglion, and thalamus. These various neurological developments have also provided a basis for a marked increase in humans' ability to actions through movement and sounds through vocalization. Alongside these changes in morphology and neurology, human society has undergone a parallel process of development involving the expansion of social groups, migrations first across Eurasia and then to the Americas, the refinement of warfare, the development of tools, and the emergence of language.

The concept of coevolution (Deacon, 1997; Givón, 1998) provides a useful framework for understanding how these various developments occurred in parallel. The theory of coevolution holds that changes in neurological and physiological structure facilitated advances in planning and communication. These advances in cognitive and communicative activities then provided an evolutionary environment that supported further neurological and physiological modifications. This notion of an evolutionary ratchet effect is fundamentally attractive. It depicts a species that is slowly and steadily moving toward fuller and fuller control over its environment. In this view, each new advance in ability should be accompanied by a greater control over the environment and a spread of habitat.

However, matters were apparently not so simple. The remarkable expansion of habitat to all of Africa and Eurasia by Homo erectus after 2MYA was not accompanied by any observable jump in the control of the material environment. Instead, it simply appeared that these hominids achieved their success through group solidarity. As we noted earlier, the expansion of the vertebrae to support nerves for the intercostal muscles at 300,000 years ago (MacLarnon & Hewitt, 1999) provides clear evidence of an emerging system of vocal communication. Yet, despite the adaptive advantages that improved communication might have provided, the population of our direct ancestors was likely no more than 10,000 at a point some 70,000 years ago (Stringer & McKie, 1996). If the story of the human race is one of the continual successful coevolution of language and the brain, we have to ask ourselves how it is that a species with some advanced level of communicative abilities had such a narrow escape from complete extinction. At the same time, one could well argue that the near extinction at 70,000 years ago provided exactly the evolutionary pressure that led to the final emergence of modern language.

The next four sections will outline how humans evolved to confront four major evolutionary challenges. Each of these major evolutionary changes played an important role in terms of providing cognitive and social bases for the development of language. This evolutionary analysis is designed to provide a basic account of the evolution of language in our species. In later sections, we will turn to the specific impact of this evolutionary past on the shape of human childhood and the acquisition of language by the child.

Bipedalism

The advent of hominid bipedal gait stands as a remarkably clear evolutionary watershed in the late Eocene. Between 10MYA and 7MYA, Africa experienced a major tectonic event that led to the formation of the Great Rift Valley. This valley runs down the center of the continent, dividing the flat jungle of the West from the more arid plain of the East (Coppens, 1999). The rift valley encompasses vast bodies of water such as Lake Tanganyika and Lake Nyasa, as well as high mountain ranges with peaks such as Mt. Kilimanjaro. The rain shadow created by these mountains produces a major discontinuity in the climate of these two parts of sub-Saharan Africa.

Before the emergence of the rift, the great apes of Africa dwelled in the warm, lush forest of the Eocene that extended across the continent. With the advent of the rift during the Oligocene, the domain of the apes became restricted to the west of the continent, ending at the rift valley. Those apes that found themselves on the east of the rift were forced to adapt to the loss of the jungle. The major competitors of the apes were the monkeys who were better able to hide from predators in the short bush and scramble for pieces of food. The challenge to the apes of East Africa was to make use of the new drier savannah habitat in a way that did not compete with the monkeys. They did this by adopting a bipedal gait. Instead of scampering about on four legs or even in a knuckle-walk posture, early hominids began to walk on their two hind legs. Australopithecines, such as Australopithecus afarensis (Coppens, 1999), were able both to climb trees and to walk with two legs on the ground. Other species, such as Australopithecus anamensis, adopted a more exclusively upright gait. The latter group included our direct ancestors.

Advantages of Bipedalism

Although we know that bipedalism was favored in the sparser habitat of East Africa, we do not understand exactly why it was so successful for many hominids. One account focuses on the fact that upright posture allows the animal to expose less body surface to the sun. Having less skin exposed to the sun decreases the impact of radiation and the need for cooling. A second factor must be the ability of the primate to use the forelimbs for other purposes, ranging from tool use to flea picking. A third factor is the defensive effect of greater height. Hunters in the veldt recognize the importance of always standing upright to convince lions, rhinos, and other animals of one's size to deter possible aggression (Kwa Maritane Guide, Pilanesberg Park, personal communication).

When we compare the great apes to the monkeys, we can see some other pressures that might have favored the move to an upright posture (Stanford, 2003). When chimps and gorillas are together in social groups, they move away from the four-legged knuckle walk position to a sitting position. This allows them to maintain better eye contact with the others in their group. In the sitting position, they do not have to bend their neck up to maintain eye contact. The shift away from knuckle walking to an upright posture continues this emphasis on body positions that allow full eye contact.

Upright posture and full eye contact also provided room for the emergence of the first gestural signals between early hominids. As many have argued, it is likely that hominids went through a period of relying on some forms of gestural communication. It is clear that upright posture provides room for such a development. However, the evolutionary

advantage of early gestures may have been overestimated, since the first bipedal primates had cognitive resources that were not yet greatly different from those of today's apes. Although we know that apes can learn and transmit a system of signs (Savage-Rumbaugh, 2000), there is little evidence that the level of sign use they display in natural contexts (Menzel, 1975) would provide any great evolutionary advantage.

The major evolutionary advantage of bipedalism is probably the fact that the forearms can then be used to hold tools and weapons (Coppens, 1995). This ability gave early hominids a clear advantage over monkeys in their search for food and defense against predators. Tools could be used to dig for roots, open termite hills, and even catch fish. Likely in response to such pressures, early hominids soon developed an opposing thumb that allowed for a stronger and more precise grasp. Because the arms were no longer needed for tree climbing, they could be committed in this way to object manipulation. Thus, this first co-evolutionary period focused on the development of new systems for control of tools through the hands.

Bipedalism brought with it a series of evolutionary costs. It placed increased mechanical pressure on the neck, the spine, and all the joints of the legs. The reliance on the feet for walking made them less able to function for climbing. The lungs had to adapt to support the breathing needed for running. However, the most important of these costs involved the narrowing of the hips (Hockett & Ascher, 1964). Because early hominids did not have a significantly enlarged cranium, this was not a problem until perhaps 2MYA. However, after that time, brain expansion ran up against the earlier commitment to bipedalism, forcing a series of adaptations in female anatomy, parturition, and child-rearing.

Tools and Imitation

The move to bipedalism opened up major cognitive challenges in terms of the control of the hands. Apes already have good control of reaching and basic object manipulation (Ingmanson, 1996). However, with both hands now always free for motion, humans were able to explore still further uses of their hands. Rizzolatti (1996) has shown that monkeys (and presumably other primates) have "mirror" neurons in the supplementary eye fields of premotor cortex that respond with equal force when an action such as "grabbing" is carried out either by the self or by the other, including a human. This mechanism provides a way of equating actions performed by the self with actions or postures performed by the other. These neurons are part of the dorsal visual system (Goodale, 1993) that allows us to represent the postural perspective of another in a way that is isomorphic with but non-identical to our own postural perspective. This dorsal system for motor matching also connects to systems in motor cortex, cerebellum, and hippocampus that represent various postures and movements of the body. These systems then connect to frontal mechanisms for storage and perspective shifting that provide a way of using our own full body image to perceive the actions of others.

Although monkeys have basic neural mechanisms that allow them to map their body image onto those of conspecifics, they demonstrate much less free use of imitation than humans. The current analysis suggests that the first evolutionary support for imitation was in the context of learning tool use. Young hominids could learn to use branches and clubs by imitating their elders. They could acquire the ability to chip one stone against

another to form primitive hand axes. The selectionist value of imitation of tool usage is clear.

The ability to imitate a series of actions requires construction of stored mental images of specific motor actions and postures. To plan the actions involved in chipping an axe, we must be able to call up an image of the desired product, and we must be able to sequence a long series of specific motions that are needed to locate good stones and devise methods for chipping edges. In this regard, the ability to construct a planned sequence of actions appears to be a unique property of hominids, as opposed to monkeys and apes. Studies of primate tool use (Anderson, 1996; Visalberghi & Limongelli, 1996) have shown that chimpanzees and capuchin monkeys can use tools in a productive and exploratory way. However, they do not appear to make planful use of mental imagery to limit their search through possible methods of tool use. Instead, they apply all directly perceptible methods in hopes that one may succeed.

Because the move to a terrestrial environment was quite gradual (Corballis, 1999), hominids needed to provide neural control for the use of the hands in both the arboreal and terrestrial environments. The arboreal environment favors the development of a specific type of motor imagery. Povinelli and Cant (1995) have noted that increases in body weight for larger apes such as orangutans make it important to be able to plan motions through the trees. To do this, the animal needs a map of the self as it executes possible motor actions. The reflexes of this penchant for postural adaptation are still evident in the human enjoyment of dance, exercise, and sport. The pressures in the arboreal environment that had favored some limited form of brain lateralization were then carried over to the terrestrial environment (McManus, 1999). This ability to shift quickly between alternative environments required neural support for competing postural and affordance systems.

Bipedalism also put some pressure on another set of neural mechanisms. Because hominids ceased relying on trees for refuge, and because they were now ranging over a wider territory, they needed to develop improved means of representing spaces and distances. All species must have some way of representing their territory. However, hominids faced the task of representing a large, often changing territory in which they were both the hunters and the hunted. To do this, they needed to further elaborate earlier mechanisms for spatial encoding. The basic neural mechanisms for this are already well developed in many mammalian species, including primates (Menzel, 1973), canines, and felines. By linking newly developed systems for action imitation to earlier systems for spatial navigation, hominids could construct mental images of their bodies moving through space and time. However, instead of just predicting body position in the next few seconds, these mechanisms could be used to predict positions over longer periods of time. In addition, hominids could use the primate system of mirror neurons to track not only the posture of conspecifics, but also their movements through space and time.

Holloway (1995) has presented evidence from endocasts (plaster casts of the interiors of skulls) indicating that there was, in fact, a major reorganization of parietal cortex after about 4MYA. This reorganization involved the reduction of primary visual striate cortex and the enlargement of extrastriate parietal cortex, angular gyrus, and supramarginal gyrus. Much of the evidence for Holloway's analysis comes from traces of the changing positions of the lunate sulcus and the intraparietal sulcus over time. According to

Holloway, the areas that were expanded during these changes in the parietal cortex support three basic cognitive functions:

1. Processing in the dorsal (parietal) stream of the visual field is important for representing actions of the other in terms of one's own body image.
2. The association areas of parietal maintain a map of the environment for navigation in the new bipedal mode.
3. The supramarginal gyrus is involved in face perception. Expansion of this area would facilitate the development of social patterns and memory for social relations.

The first two of these functions are directly related to the developments that resulted from the adoption of bipedal gait. The third function may have played a large role during the next period in which the focus of evolution was on social cohesion.

Social Cohesion

The shift to bipedalism is clearly documented in the fossil record. However, fossils speak only indirectly about the evolution of primate social structures. Even basic facts about hominid group size are difficult to determine from the spotty fossil record. We do know, however, from studies of current primate groups, that larger groups provide better protection for group members, particularly the young. We also know that maintaining larger groups requires refinement of methods for social communication and food gathering. This section explores the ways in which pressures toward larger group size led to the evolution of mechanisms for social cohesion. The developments we discussed in the previous section lead directly to increases in individual fitness. For example, if a young hominid can use imitation to learn how to chip an axe, that individual will be more able to kill prey and to survive attacks from predators.

Evolutionary support for the development of social features tends to rely more heavily on mechanisms for mate selection. A prime case of this is imitation in both the auditory and visual modes. Individuals with high levels of imitative skill are likely to attract mates by entrancing their attention. Females who respond sexually to imitative (communicative) males will be likely to produce offspring who are themselves imitative, thereby following the selectional route of producing "sexy sons." At the same time, infants who respond imitatively to their mothers may receive better nurturing, thereby improving their chances for survival. As a tendency toward imitation spreads through a group, those individuals who are less capable of face-to-face imitation will receive less social support and will be dispreferred as mates. Although there will always be some ecological niches for individuals with low imitation ability, the general trend in the population will be toward continually improved imitation skill.

Vocal Support for Social Cohesion

As group size increases, there is increasing conflict for food, rank, control, and access to females. Dunbar (2000) argues that primates developed a large neocortex to deal with these tensions. However, other primate groups have been able to develop methods that maintain social cohesion that do not require radical changes in brain size (de Waal & Aureli, 1996). Moreover, hominids came under pressure to maintain large social groups well before there was a significant expansion in brain size. In particular, between

4.5MYA and 3.5MYA the hominids in East Africa went through an expansion of their range and a proliferation of species. This proliferation was then followed by a period of tight competition with range contraction (Foley, 1999). During this period of range expansion and contraction, our ancestors did not improve their social organization simply by growing larger brains, although brain size did increase a bit, mostly allometrically (Holloway, 1995). Instead, as Nettle and Dunbar (1997) have argued, it is likely that the hominids of the Pliocene consolidated their group structure by a set of targeted neural-behavioral adaptations. Chief among these, I would argue, is the subordination of the vocal system to cortical control.

Our Pliocene ancestors probably possessed a set of vocal calls much like those used by other primates. It was not the emergence of new sounds that supported social cohesion, but the ability to use old sounds in new contexts. By calling up specific calls and gestures at will, our ancestors were able to use chatter to gain the attention of their compatriots to negotiate the basics of group relations. The fact that the great apes did not go through a parallel evolutionary process in West Africa can be attributed to the different requirements on group size in their arboreal habitat and the fact that they had not adopted bipedal gait and its resultant improvements in face-to-face communication.

One of the side effects of an increase of cortical control over vocalization might well be the ability of hominid groups to lock in patterns of vocal behavior that characterize the local group, as opposed to the wider hominid community. At first, these local forms of communication would not be sharply defined. However, as the mechanics for vocalization come increasingly under cortical control, it would become easier for a group to differentiate itself from others by unique vocal features that would transmit over a distance. Songbirds achieve this effect through species-specific processes of vocal learning (Konishi, 1995). In birds, dialects allow individuals and groups to maintain their territory against competitors. Hominids could achieve the same effect through differentiation of local patterns for speech and gesture.

Neural Modifications

Achieving neocortical control over the vocal-auditory channel required neuronal reorganization without a major increase in brain size. Ploog (1992) has shown that humans have more direct pyramidal connections between motor cortex and the speech and vocalization areas of the brain stem than do monkeys. Certain areas of the limbic system, such as the anterior thalamic limbic nuclei, have grown disproportionately large in humans. These nuclei serve the supplementary motor area and premotor and orbital frontal cortex. The expansion of these structures points to increased limbic input to the cortex as well as input from the cortex to the limbic structures. Tucker (2001) shows that the basic adaptation here involved the absorption of the primate external striatum by the neocortex (Nauta & Karten, 1970).

In macaques (Jürgens, 1979), control of the vocal system relies on the periaqueductal gray matter of the lower midbrain. Additional midbrain regions can stimulate the periaqueductal gray, but the neocortex does not control or initiate primate vocalizations. In humans, on the other hand, electrical stimulation of both the supplemental motor area and the anterior cingulate of the frontal cortex can reliably produce vocalization. Primates make few attempts to structure local dialects or otherwise structure their call system

through learning (Seyfarth & Cheney, 1999). Yerkes and Learned (1925) and others have tried to condition chimpanzee vocalizations in the laboratory and have failed. Human infants, on the other hand, rely at least in part on highly plastic cortical mechanisms to control vocalization. This allows them to pick up the sound patterns of their community through mere exposure. As a result, each hominid group can build a local vocal accent that is passed on to the next generation through mere exposure. Other aspects of communication, such as conversational sequencing (Trevvarthen, 1984), may be more linked to modeling and imitation. However, this learning of conversational functions only occurs because the child is locked into the interaction by motivational forces that reward face-to-face vocalization (Locke, 1995).

Although primate vocalization is not under cortical control, it has an extremely direct connection to midbrain motivational areas (Pandya, Seltzer, & Barbas, 1988). Human language continues to rely on this underlying limbic architecture to provide emotional coloring to vocalization. As Tucker (2001) argues, the linkage of the vocal system to limbic mechanisms provides grounding in terms of arousal (brainstem and amygdala), motivation (basal ganglion), patterning (striatal-thalamic circuits), and memory (limbic circuits). Humans also retain some direct links between audition and these limbic circuits, as evidenced in the directness of our responses to sounds such as infant cries or the growls of predators.

The linkage of vocalizations to cortical control allowed our ancestors to distinguish themselves from other hominids. It also allowed them to build up a system of face-to-face social interactions. MacNeilage (1998) has argued that the primate gesture of lip smacking is the source of the core CV (consonant-vowel) syllabic structure of human language. The CV syllable has the same motoric structure as lip smacking. Moreover, it is produced in an area of inferior frontal cortex close to that used for lip smacking and other vocal gestures. Primates use lip smacks as one form of social interaction during face-to-face encounters. However, even bonobos, the most social of all primates, do not maintain face-to-face conversations for the long periods that we find in human interactions. Obviously, one must go beyond a boring repetition of lip smacking to maintain a reasonable level of sustained face-to-face vocal contact. Increased cortical control of vocalization allowed our ancestors to begin the process of developing these elaborations. By linking its members into tight affiliative relations through face-to-face interaction, our ancestors achieved a form of social organization that allowed them to maintain large social groups for defense against other hominid groups.

The discussion so far has emphasize the role of auditory imitation. However, an equally compelling argument can be made for the importance of growth in visual imitation. To maximize the effectiveness of face-to-face interactions, hominids also needed to bring the production of facial gestures under cortical control. As in the case of the control of tool use through motor imagery, humans differ from monkeys (Myers, 1976) and apes (Gomez, 1996) in the extent to which the cortex can produce gestures upon demand.

In considering the role of face-to-face vocalization in hominid groups, we must not forget the possible divisive role played by aggressive males (Anders, 1994; Goodall, 1979). Hominid groups relied on aggressive males for their skills as hunters and their ability to defend the group against attack. However, groups also needed to provide ways to avoid the direction of male aggression toward other members of the group, particularly

other males. We know that primates had already developed various methods for handling these conflicts, including exile for problematic males, the formation of master-apprentice relations, and development of male social groups. Within this already established social framework, males could also benefit from ongoing reaffirmation of their social status through face-to-face chat. By socializing young males into this productive use of language for social cohesion, mothers could also contribute to the stability of the group. Breakdowns in these processes could threaten the survival of the group and even the species.

This account has emphasized the importance of cortical control over the vocal apparatus. There is no evidence that there was a corresponding evolution of auditory abilities in hominids. The reason for this is that it appears that primates have already achieved a level of auditory processing ability sufficient to support analysis of all vocal communications (Hauser, Newport, & Aslin, 2001; Kuhl & Miller, 1978). There is currently no reason to believe that the human auditory system underwent any major adaptation in the last six million years. The linkage of vocal and facial expression to cortical control may seem like a fairly trivial neurological adaptation. However, it helped our ancestors through this period of intense competition between groups and set the stage for the major changes that were to come in the next period.

Mimesis

By 2MYA, Homo erectus emerged victorious from the period of intense competition with other hominids. Recent analysis points to Homo ergaster, rather than Homo erectus as the direct ancestor of Homo sapiens. However, the details of the relations between Homo erectus and Homo ergaster are not yet clear. In this paper, I will refer to these two related populations as Homo erectus, understanding that the details of this particular lineage may soon be revised.

During this period, the species had achieved some level of group solidarity through the social use of imitative vocalization and gesture. Beginning sometime before 2MYA, our ancestors were confronted with a third major evolutionary opportunity. Having committed themselves to face-to-face communication, and having elaborated their basic systems of social identification and imitation, the first groups of Homo erectus were then able to elaborate new forms of symbolic communication in both vocal and gestural modalities. These new systems involved the spontaneous interaction of vocalizations, postures, and gestures in specific social and pragmatic contexts. Although the intertwining of these systems could serve admirably for maintaining shared attention and social cohesion, it would have proved difficult to link these spontaneous systems to a method for traditional transmission (Hockett, 1960). Vocalizations were just now coming under cortical control and had not yet been systematized in a way that would guarantee productivity and replicability. Gestural and postural patterns probably played a more central role. However, their iconic and situated nature may have served as a barrier to abstract systematization. To the degree that gestures could be made up “on the fly” there would be little evolutionary advantage supporting systematization.

Darwin (1877) thought it unlikely that a system such as language could have emerged directly from gesture. He believed that this would require the shifting of a function from one organ to another and then back again, as if flying had moved from the wing to the stomach and then back to the wing. However there is no reason to think that Darwin

would have excluded the possibility that gesture and vocalization underwent co-evolution. Today, speech and gesture complement each other during communication (McNeill, 1985). Some messages are conveyed through speech, but others are conveyed through the hands and the posture. Still other messages are conveyed by changes in the tone of voice. It is likely that each of these channels of communication were also available to Homo erectus and that they functioned in an interactive and complementary fashion, much as they do now.

Advantages of Mimesis

Donald (1991) has emphasized the central role of what he calls “mimesis” in the communicative world of Homo erectus. Mimesis involves communication about actions, plans, feelings, and objects through iconic depiction of parts of those actions, states, and objects (see also Nelson, this volume). The depiction may conjure up an image of an object by gesturing its shape or imitating its sound. Actions can be depicted by repetition of their central components. In general, mimesis achieves reference through partonymy, or mention of a part to express the whole. Mimesis can be expressed through signing, chant, song, drama, ritual, and basic forms of costume. To be maximally effective, these systems must occur within fixed social contexts that guarantee attention and some traditional form. As conventionalization advances, mimetic systems can support group solidarity, planning, and socialization in an increasingly structured way. Through conventionalized chant and dance, the male society can plan hunts and battles and reenact past struggles. At the same time, mothers can use song, sound play, and chant to hold the attention of their young children while socializing them into the practices of the community. Mimetic processes are linked to the emotional use of language that was elaborated during the previous evolutionary period. As a result, mimetic communications can be used to move people emotionally, preparing them for war, migration, or other major group activities.

It appears that mimesis was enormously successful in providing social cohesion and shared planning. As a result, Homo erectus was able to expand its territory to all of Africa, eventually leading to the extinction of all other hominid species. It also allowed Homo erectus to migrate successfully out of Africa to all parts of Asia, including the Middle East, China, and Indonesia. We should attribute this successful expansion to two basic processes. The first was an ability to eliminate competitors, particularly in Africa. To do this, erectus must have relied on group solidarity as a support for warfare. Second, to support the migration to new territories, erectus must have been extremely adaptive. This adaptivity could not have been grounded in some simple physical change. Instead, it must have resulted from a general improvement in cognitive capacity, particularly as reflected in group problem solving and adaptation.

MacWhinney (1999a) and Tomasello (1999) have developed parallel accounts of these changes that emphasize the importance of being able to take the perspective of another human being as an intentional agent. In both accounts, this ability is a precondition to the full successful use of language. Tomasello locates the emergence of this ability in the period after 200,000 years ago. However, like Donald (1991), MacWhinney sees the ability arising as early as 2MYA with ongoing developments during more recent periods. The account developed here emphasizes the initial role of

social cohesion as an evolutionary support for communication. The movement to an upright position allowed us to engage more directly with our conspecifics both gesturally and vocally. The rise of cortical control over vocalization led to further improvements. However, to take full advantage of face-to-face communication, we needed to expand our image of the other. Supports for this include neural control of imitation (Decety, Chaminade, Grezes, & Meltzoff, 2002), face recognition (Moskovitch, Winocur, & Behrmann, 1997), and the construction of a full projectable body image (Ramachandran & Hubbard, 2001). These new developments could rely on some parallel evolutions that had been occurring outside of the social realm. Because the movement to an upright posture freed the hands for increased use of tools, hominids derived additional evolutionary advantage from the formation of mental models of plans for tool usage and action schemas. These schemas relied on the development of a mental model for the self's activities. This same mental model could then eventually be projected onto the other, allowing hominids to develop increasingly sophisticated ideas about the future actions of others. However, without further support from language, this level of theory of mind construction could only go so far.

Neuronal Adaptations

The brain Homo erectus tripled in size during the period between 2MYA and 100,000 years ago. Some of this increase is allometrically related to the overall growth in stature during this period. Thus, it might be better to speak of a doubling in size, rather than a tripling in size. The brain expanded in size because the preconditions for a successful expansion were now all in place. In particular, previous evolution had already produced at least these five abilities:

1. The shift to bipedalism had freed the hands for gestural communication.
2. The freeing of the hands for tool use had led to further elaboration of primate mechanisms, such as “mirror” neurons, for representation of the actions of others.
3. During several millennia of migration and population movements across open ground and through the bush, our ancestors had developed systems for tracking their own spatial positions in the present, past, and future, as well as the spatial positions and perspectives of others.
4. Our ancestors could use their visual system to generate images of past actions and spatial configurations involving themselves and others.
5. During the period before 2MYA, our ancestors had developed a tight linkage of attention to vocalization processes during face-to-face interaction and imitation.

These developments provide preconditions for the evolution of mimesis. To further support mimesis, the brain needed to provide complete episodic storage for combinations of gesture and vocalization. It had to store whole chants or gestures as they expressed particular events of importance to individuals and the group. Some of these chants and gestures might be rather extended. For example, there might be a dance that represented the time of ripening of the mongongo nut or one that outlined the components of the hunt for the eland. At the same time, these larger mimetic sequences would be composed of smaller pieces that had achieved other cognitive-social grounding. For example, by

pointing to a place in the area around the group's encampment, the dancer could signal the direction of a hunt. By holding his arm in a particular stance, the dancer could mime the attack on the game. These component gestures, movements of the body, and vocal chants could then be reused with other components in a relatively unsystematic fashion.

Unlike the evolutionary pressures of earlier periods, the storage and retrieval of conventionalized mimetic sequences cannot be achieved simply by linking up older areas or by reusing earlier connections. Instead, the brain must add new computational space to store the multitude of new visual and auditory images. In addition, the brain needs to expand the role of the frontal areas for storing and switching between perspectives. Because this system grew up in a haphazard way from earlier pieces of lip smacking, pointing, gesture, and rhythm, it would be difficult to extract a core set of elements from mimetic communications. Instead, patterns and forms must be learned and stored as holistic unanalyzed sequences. This Gestalt-like shape of early mimetic patterns corresponds well with the Gestalt-like cognitions that we develop through our interactions with objects (Gibson, 1977). For example, when we chop wood, there is a complete interpenetration of muscle actions, visual experiences, hand positions, and sounds. We can think of this as a single merged form such as I-hands-back-lift-axe-drop-split-chips-wood-cut. Mimetic forms have this same unanalyzed quality. This lack of analysis is not the result of chunking or automatization, since the Gestalt is not constructed by a system of combinatorial semantics. Instead, each chunk is a raw, unanalyzed whole that is fully grounded on direct action and perception. Because they are highly grounded on our direct perceptions and actions, they communicate in a basic way. However, they provide little support for cognitive organization.

The growth of the brain in response to these pressures was so rapid that it is typically assumed that it involved a single genetic mechanism. One such mechanism might involve regulatory genes (Allman, 1999) that control the development of structures in the fetus. Changes in the timing of the expression of these genes can lead to the observed across-the-board increase in size for the cortex and cerebellum that we see in Homo erectus. However, the expansion of the cortex placed additional adaptive pressures on Homo erectus. The bigger brain required a much greater level of caloric intake. This pressure could be met through changes in diet and modifications to the digestive system. A more fundamental pressure was the fact that increases in the size of the infant brain produce problems for the birth process. The width of the hips had narrowed in both men and women as a response to bipedalism. As long as the skull was not much larger than that found in the great apes, this did not cause major problems for the birth process. However, the expansion of the skull in Homo erectus ran directly into this evolutionary barrier. To deal with this, the infant is born at a time when it is still fairly immature and the skull is relatively pliable. The increasingly organized shape of the society facilitates the survival of the child. In addition, women have had to sacrifice their ability to run quickly so that the hips could widen, permitting births with larger infant heads. The slowing of infant development not only helps in the birth process, but also helps the child maintain cortical plasticity (Elman, Bates, Plunkett, Johnson, & Karmiloff-Smith, 1996; Julesz & Kovacs, 1995) even into adolescence, thereby further enhancing the ability of the group to construct accepted mimetic patterns.

Systematization

By the end of the Pliocene, Homo erectus had achieved dominance over its hominid competitors. There were no remaining hominid species in Africa. Homo erectus had eliminated its competitors either through warfare or resource competition, and had successfully migrated to Eastern Europe, Asia, and Indonesia. However, with the onset of the glaciations of the Pleistocene, our ancestors came under increasing pressure to adapt to the colder, drier environment. At this point, there was a contraction of territory back to Africa. Beginning about 200,000 years ago we can talk about the emergence of Homo sapiens, or modern man, as a new species. The analysis of mitochondrial DNA (Cann, 1995; Cavalli-Sforza, 1991; Templeton, 1992) allows us to trace the lineage of all current humans back to a single population and perhaps a single mother that lived in Africa about 200,000 years ago. Beginning from this time, modern people migrated again out of Africa to the Middle East and Europe. However, at about 70,000 years ago there was a near extinction that brought the number of our direct ancestors down to only 10,000 individuals worldwide. Of course, this population may well have coexisted with other hominids, such as the Neanderthals, who are not our direct ancestors.

After the recovery from this near extinction, humans went on to achieve major cultural and material breakthroughs in the Neolithic, including the remarkable cave paintings in Europe and the settling of Australia, the Americas, and Polynesia. The fact that the brain expansion of Homo erectus was not enough by itself to trigger the emergence of material culture helps us to understand the shape of recent processes in human evolution. Instead, humans needed some way to systematize the growth in mimetic processes that had occurred during the Pliocene. The core of the new system involved the introduction of a set of phonological contrasts (Hockett & Altmann, 1973). To achieve accurate articulation of these contrasts, a further set of adaptations was needed for the serial ordering of actions and the precise articulation of sounds. These adaptations included loss of the canines, adaptation of the arytenoids, bending of the vocal tract (Lieberman, 1975), and shaping of the musculature of the tongue. Each of these modifications led to a separate and meaningful increment in our ability to articulate clearly a full inventory of phonetic contrasts. The complex and diverse nature of these modifications suggests that the phonetic revolution occurred not in a single leap, but gradually across the period from 300,000 to 50,000 years ago. It is likely that those individuals who survived the evolutionary window at 70,000 years ago were those who had made the greatest progress in terms of consolidating this phonological ability and the group planning which it facilitates. The fact that many children still show evidence of language disorders due to both neurological and physiological problems indicates that this process of systematization continues to unfold evolutionarily even today.

Selection for language-related proficiency is driven primarily by mate selection, with both women and men preferring mates who are able to imitate, articulate, and conceptualize effectively (Miller, 2001). Language can be used to construct the love and friendship that underlie many sexual relations, and to provide ongoing detection of cheating in these relations. At the same time, much of the evolutionary success of language-based courtship may derive from the use of language to deceive. By creating fictive mental images of faithfulness and pair bonding, men can attain sexual favors from women, even without being truly faithful (Buss, 1999). Strategies of this type correspond to what we would now call “a smooth talker.” An even greater advantage accrues to

males who take on roles of charismatic group leader. For example, it is claimed that the rock star Jimmy Hendrix fathered well over a hundred children. Although such estimates may be difficult to verify, the ability of dominant males to secure larger numbers of females for reproduction is common in many species. What is unique in humans is the fact that the ability of a leader to achieve charismatic control is often achieved through activities such as political speaking, military display, and various forms of artistic expression.

Perspective, lexicon, and grammar

The development of smooth methods for articulatory planning opened up possibilities for the construction of a mental lexicon. By coding words into a compact set of contrastive features, Homo sapiens was able to conventionalize, learn, store, and retrieve a virtually limitless set of names for things. However, by itself, the emergence of a lexicon is not enough to produce full human language. People also have to make use of a system for combining words into sentences. However, this basic combinatorial ability to control plans and strings of conventionalized actions had already been developing in a primitive form during the mimetic period with Homo erectus. Thus, the flourishing of language after about 70,000 years ago involves a linking of the new lexical power with an older mimetic power. Like the older mimetic system, the new syntactic system relies heavily on the tracking of perspective. Elsewhere (MacWhinney, in press), I explain in detail how syntax and grammar emerge from the online tracking of perspective flow in sentences. This ability to track perspectives depends heavily on the imitative abilities that had been developing for nearly three million years, as well as the planning and mimetic abilities that had been developing for nearly two million years. However, when planning and mimesis are taken out of the concrete visual mode and constructed through the auditory mode, they place a greater load on abilities to construct and store alternative perspectives and mental models. Thus, it seems to me that the critical development between 70,000 and 40,000 years ago involved the growth of an ability to control perspective-taking in the auditory mode. Those individuals who possessed this ability were able to rise to the top of Neolithic society as priests who could express a spiritual vision and as leaders who could express a vision of conquest.

Advantages of the New System

With the power of a systematized lexicon, people could easily name and encode all of the important objects, properties, and actions in their environment. Having a full inventory of the physical world allowed early humans to use different animal and plant species for increasingly refined purposes. This new lexical richness became particularly powerful when it was embedded in the perspective shifting system. Pinker and Bloom review some of the core linguistic constructs, such as tense, deixis, and transitivity supporting this expansion (Pinker & Bloom, 1990). For example, by forming complex locative descriptions, language was used to pinpoint the location of quarry sites for flints and other materials for stone weapons and tools. Master craftsmen used language to teach apprentices how to chip points, prepare hides for tanning, carve out wooden bowls, bind

axes to poles with sinew, sew hides into tents, and tame pets. As tool-making progressed, language was used to explain how, where, and when to plant and water seeds. By codifying these times and practices in verse and religion, the first agricultural systems were developed and shortly thereafter the first settled villages, such as Catalhöyük in Anatolia at about 9000 B.C. From these roots, came the civilizations of the ancient Middle East, Egypt, and China with their invention of writing, organized warfare, chariots, metallurgy, government, and increasingly formalized religion. Modern society has elaborated on this foundation with the creation of cities, books, bombs, law, medicine, and the Internet. All of these developments are consequences of the introduction of systematization for phonology and lexicon. However, this recent expansion would not have been possible without the major cognitive modifications of the preceding 6 million years of human evolution.

Neuronal Adaptations

Many of the adaptations required for smooth vocal production are quite peripheral (Lieberman, 1973), involving changes to the vocal tract, the structure of the larynx, muscle innervation, tongue support, and facial musculature. Some of these changes were underway before the Pleistocene; others have been more recent. To control this additional external hardware, the brain has needed to fine-tune its mechanisms for motor control. This fine-tuning does not require the type of brain expansion that occurred in Homo erectus. Instead, it involves the linking of inferior frontal areas for motor control to temporal areas (Gabrieli, Brewer, Desmond, & Glover, 1997) for sequence storage. These linkages involve pathways that lie under the central sulcus. They constitute a functional neural circuit that implements a phonological loop for learning new words (Gupta & MacWhinney, 1997). The auditory shapes of words are stored in topological maps (Miikkulainen, 1990) in superior temporal auditory cortex and can be associated to visual images in inferior temporal areas.

Once Homo sapiens had achieved an ability to produce, store, and learn a large vocabulary of phonologically organized forms, the remaining steps in the evolution of language were comparatively easy. Humans had already achieved a mimetic system for perspective taking and perspective switching. This system allowed listeners to mentally reenact the motions, rhythms, and chants of the speaker as they depicted movement between places and actions on objects. Once words became available, speakers and listeners could parse these single-package Gestalt-like communications into their components. With words to name specific objects and participants, it was possible to separate out nouns from verbs. This adaptation to grammar required no particular new cognitive skill for nouns. However, for predicates such as verbs, it was important to store linkages between the overall configuration of the action and the specific uses with participants. In other words, children had to learn how to manage language in terms of item-based syntactic constructions (MacWhinney, 1975, 1982) and phrasal collocations, including “verb islands” (Tomasello, 2000). Neuronal processes for this level of control involve little in the way of new evolution. However, they place storage demands on the pathways between the temporal lexical areas and the frontal planning and sequencing areas.

As speakers build up longer and longer strings of propositions, they rely increasingly on frontal areas, such as dorsolateral prefrontal cortex (DLPFC) for the storage of one perspective that allows shifting to a secondary perspective. Shifts of this type are central in the processing of anaphors and gaps in argument structure. As MacWhinney (1999a) has shown, these various syntactic processes are grounded not on the construction of abstract syntactic trees, but on the direct processing of embodied perspectives of the type that were also important during the period of mimetic communication.

Developmental Considerations

Having now reviewed the overall course of language evolution, we are in a position to assess linkages between evolution and the development of language in the infant and child.

Recapitulation

In this area, one theory that immediately suggests itself is the idea that language ontogeny in the child recapitulates language phylogeny in the species. In some regards, this may well be the case. For example, the cries of the newborn are driven exclusively by brainstem and midbrain mechanisms. It is not until well after the third month that infants begin to demonstrate some cortical control of vocalization. Although they have some imitative abilities soon after birth (Meltzoff, 1988), these abilities rise to important new levels toward the end of the first year (Bruner & Sherwood, 1976). We see major advances in lexical organization toward the end of the second year (Gershkoff-Stowe, Thal, Smith, & Namy, 1997) and a consolidation of articulatory abilities even later (Menn & Stoel-Gammon, 1995). Perhaps the final crown on the course of language development occurs during the acquisition of complex syntactic expressions to control perspective shifting lexically and syntactically (de Villiers & de Villiers, 1999). But the synchrony of these events is certainly not exactly that appearing in evolution. After all, children babble well before they walk and we know that our ancestors became bipedal long before they achieved full cortical control of vocalization.

Traditional transmission

It is perhaps rather more fruitful to ask a rather different set of questions about the role of language evolution in human development. Specifically, it seems important to focus on the fact that human language is transmitted traditionally from generation to generation. In order to achieve this cultural transmission, evolution needed to operate in detail on the relation between the child and the mother. In the terms of Bjorklund and Pellegrini (2000), we can say the evolved psychological mechanism of language itself undergoes development during human childhood. The pivotal mechanism here is the linkage between the mother and the child, particularly in the first year (Locke, 1993). Although primate mothers are devoted to their young, they do not engage in the types of continual face-to-face vocal interaction that we see from human mothers. Few would doubt the central role of early mother-child bonding. However, in many cultures, after the

first year, children are raised by co-wives and older siblings. Thus, there is no universal requirement that the mother should be the only person teaching language to the child. Instead, much of language learning after the first year rests on the shoulders of children who seem to soak up the speech patterns of those around them as if they were linguistic sponges. Of course, the ability to learn language does not terminate during childhood, since we can learn second languages well into adulthood, albeit with a noticeable foreign accent.

Demodularization

Language is grounded on the evolutionary achievements of the past 6 million years. However, once language is available as a method of cognitive representation, cognition itself is fundamentally altered. The most remarkable property of human language is that it has smooth and nearly immediate access to the entire brain. Through this ability to integrate across modalities and modules, language is able to overcome modularity and open up the mind to fully human consciousness. Language relies on the entire brain to achieve its complete cognitive simulation of experience in terms of objects, space, action, and social relations. Because it integrates these separate modules so thoroughly, it allows us to fully escape the modularity that is present in primates (Russon & Bard, 1996) and young children (Hermer-Vazquez, Moffet, & Munkholm, 2001). Without language, it may be possible to focus directly on the position of an object without regard to earlier orientations or the orientations of others. Without language, we can focus on an action without breaking it apart into its component participants. In order to achieve lexicalization, language forces us to analyze experience into its components (Gentner, 1982). Although language forces us to break our experiences into pieces, it provides ways of then recombining these pieces into much larger edifices. Moreover, narrative and discourse allow us to integrate our own experiences more fully with those of others. In this way, language bundles the whole of mental life into a single, more fully conscious, but relatively less grounded whole.

Because language is a human invention, the brain provides us with a great deal of latitude in the way it can be represented. As Wittgenstein (1953) observed, language is like a well-pruned hedge. Externally, each hedge must look like the others. However, internally each hedge can have a very different shape. This means that we should not be surprised to find large individual differences in the neuronal basis of higher-level dynamic control for language. For example, children with large focal lesions to the left hemisphere areas that typically control language are able to achieve normal language functioning by using parallel areas in the right hemisphere (Booth, MacWhinney, & Harasaki, 2000). Several patterns of reorganization to damage have been identified for young children (MacWhinney, Feldman, Sacco, & Valdes-Perez, 2000) and similar reorganization certainly occurs in adults (Holland et al., 1985). In addition to the flexibility found in patients with brain lesions, there are important individual differences in the way that the brain organizes for language in normally developing speakers. In particular, it is likely that the process of cerebral lateralization operates in very different ways in different children, with some making a sharp separation between the functions of the two hemispheres (Beeman et al., 1994) and others allowing for more redundancy.

The Child's Construction of Social Reality

Although the emergence of systematization in Homo sapiens required little or no expansion in brain size and only limited reworking of neural connectivity, it has had major consequences for the way in which we use our brains. Vygotsky (1962) showed how language begins as an external social phenomenon and is then internalized to provide the backbone of human cognition. Vygotsky attributed this internalization to the emergence of “inner speech” and compressed forms of reference and topicalization, but provided little additional detail regarding his proposal. Tomasello (1999) and MacWhinney (1999a) extended Vygotsky's analysis by linking language learning to the child's ability to treat others as intentional agents. This assumption of an intentional stance helps the child follow the meaning of the parent when learning new words. Tomasello also shows how intentionality allows the child to construct the representations underlying causal predications. Infants will extend intentionality even to inanimate objects, when they have eyes that represent a face (Gergely, Nádasdy, Csibra, & Bíró, 1997) or even when they do not but appear to have intention (Csibra, Gergely, Bíró, Koos, & Brockbank, 1999). Later, through fictive extensional processes (Lakoff, 1987; Talmy, 1988), children treat even inanimate objects as acting intentionally and causally.

This system of causal representation forms the basis for grammatical processes such as case marking, conflation, passivization, inverse, and causitivization. For example, when listening to the sentence “The dog the man chased caught the ball,” we begin by taking the perspective of the “dog” as the sentence subject. However, when we begin processing the relative clause, we shift our causal perspective to “the man” who then becomes the one who chases the dog. However, once the relative clause is finished, we need to return to the perspective of the dog that is catching the ball. In even such a simple example as this, we can see that the smooth production and comprehension of grammatical structures involves a continual shift between perspectives. In fact, MacWhinney (1999a; in press) argues that grammar arose specifically for the purpose of representing these perspective shifts. It is difficult to imagine how Homo erectus, without systematized methods for producing words and without additional grammatical devices for marking perspective shifting, could have achieved anything close to the level of narrative flexibility that Homo sapiens can achieve through fully grammaticized language.

By providing technical methods for encoding and decoding perspective shifts, grammar allows us to construct increasingly complex social relations. In these relations, we often need to take the perspective of the other and imagine how that person will react to a variety of possible actions that we might perform. In practice, we select the exact shape of a given utterance or action out of a much larger field of potential actions based largely on this act of social perspective-taking. Would our utterances offend some particular individual? Would they violate some moral precept? Would we fail to properly articulate our position and therefore leave ourselves open to later misinterpretation? As we compute these various possible scenarios, we use the three lower levels of perspective-taking (direct perception, space-time, causal action) to move about in a conceptual space that was constructed through linguistic interactions embedded in a social context. These processes allow us to construct enormously complex systematic (Levi-Strauss, 1963) views of social structure. Yet the cognitive resources we are using are little more extensive than those available to Homo erectus. Instead, through the

construction of a method for creating new words, we have been able to reuse our mimetic resources to support the full articulation of human culture. In this sense, the appearance of modern language is a paradigm case of an emergent behavior (MacWhinney, 1999b).

Disorders of Communication

Genetic theory would lead us to believe that those adaptations that are most recent should be the ones that are least fully integrated into the human genome. Because the systematization of articulation in the interests of lexical structuring emerged relatively late in evolution, it is not surprising that we find extensive problems in these areas of motor control:

1. stuttering: a process that involves problems in the activation and coordination of output processes based on individual lexical items,
2. dysphagia: problems with chewing and swallowing that may reflect some instability in the rewiring of innervation of the vocal tract,
3. articulation disorders: between the ages of 4 and 8, many children have problems articulating the exact shapes of words. Disorders such as lisping sometimes continue into adulthood.
4. tongue curling: about 30% of the adult population cannot perform the type of tongue curling or the type of tongue bending needed to properly articulate sounds such as the retroflex stops of Hindi. There are similar problems with the articulation of one of the three Czech r-sounds.

There is good reason to believe that these disabilities represent incomplete consolidation of recent evolutionary changes. If we then further parcel out cases of mental retardation¹, autism², fetal damage, and chromosomal abnormalities³, we are left with a group of children who are said to have specific language impairment (SLI). The incidence of some form of specific language impairment in the population is often estimated to be about 7%. In the clinic, language disorders are nearly four times more frequent in males than in females (Bishop, 1997). However, epidemiological studies have shown that the actual balance in the population is nearly equally distributed between the sexes (Leonard, 1998). Once we parcel out the children with primarily motor problems and those with serious nonlinguistic impairments, we are left with children who seem to have problems organizing the flow of syntax. Recent studies (Franks & Connell, 1996; van Der Lely & Stollwerk, 1997; van der Lely & Stollwerk, 1996) have suggested that children with grammatical disorders have a specific problem with argument chains. Within the context of the current analysis, this could best be viewed as a deficit in the ability to switch perspective. Note that these children are able to shift perspective in simple clauses. It is the processing of complex and multiple perspective shifts in grammar that causes them problems.

Although some children will display various forms of language disorders, these disorders are never so severe that they fully block the acquisition of human language. This is because the acquisition of language is protected by a system of multiple buffering. Some children may learn through analysis, others through auditory encoding, and others through direct imitation. If one of these systems is partially blocked, the others can operate. Moreover, there is no human group that does not have language, and the core aspects of language learning, although they may differ somewhat in timing, are

essentially universal. Some take this as evidence for a recent evolution of Universal Grammar. I would argue instead that it indicates the extent to which language capitalizes on our shared human nature.

Conclusion

The study of language evolution has made solid advances in recent years. New evidence from the fossil record, paleoclimatology, genetic analysis, neuroscience, infancy research, and cognitive grammar has fueled these advances. As the database of evidence regarding human's last six million years continues to grow, we will be able to articulate increasingly precise ideas about the co-evolution of language, brain, and social processes. Modern human children illustrate the ongoing and dynamic nature of this evolution. To learn language they depend on systems of imitation, empathy, mimesis, play, articulation, lexicalization, and perspective switching that have developed across millions of years. At the same time, they use language during their own lifetimes to elaborate new cultural objects and ways of thinking.

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