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Origins of the language: Correlation between brain evolution and language development

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Introduction

The question about when and how language emerged in human evolution has been a major and intriguing question since at least the classical Egyptian times. It is reported that the Pharaoh Psamtik took two children to be raised by deaf-mutes, in order to find out what was the first and natural language. When these children were later observed, one of them said something that sounded like *bekos*, the Phrygian word for *bread*. From this, Psamtik concluded that Phrygian was the first and original language. During the following centuries, the origin of language continued as a most intriguing and polemic question. Different approaches and interpretations were proposed throughout the history. At a certain point, the debate became so complex and hot, that in 1866 the Linguistic Society of Paris banned discussion of the origin of language, arguing that it to be an unanswerable problem.

Contemporary research on linguistics, archeology, comparative psychology and genetics has significantly advanced in understanding the origins of human language (e.g., Bickerton, 1990; Corballis, 2002, 2006; Enard *et al.* 2002; Mallory, 1989; Nowak and Krakauer, 1999; Ruhlen, 1994; Swadesh, 1967; Tallerman, 2005). Different disciplines have contributed from their own perspective to make human communication system more comprehensible.

The purpose of this paper is not to further review and discuss the historical origins of language, but to relate what is known (or supposed) on the origins of language, with contemporary neurology and neuropsychology data, particularly, with the area of aphasia. Aphasia knowledge can potentially also make a significant contribution to the understanding about the origin and evolution of human language.

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Initially, some basic neuropsychological data about language impairments in cases of brain pathology will be presented. It will be emphasized that there are two basic linguistic operations (selecting and sequencing; i.e., language as a paradigm and syntagm) (Jakobson and Halle, 1956; Jakobson, 1971). There are also two basic types of aphasia syndromes named in different ways (e.g., motor/sensory; anterior/posterior; nonfluent/fluent; Broca-type/Wernicke-type; encoding/decoding disorder; expressive/impressive disorder, etc.), each one related to the disturbance of one of these two basic language elements (lexical/semantic and grammatical). Hence, in considering language evolution these two different dimensions of language have to be recognized. Each one may have emerged at a different historical moment. Analyzing this basic distinction and including it in an interpretation about language evolution can potentially further language evolution understanding.

There are only two fundamental aphasia syndromes

Since the nineteenth century it is well known that there are two major aphasic syndromes, named in different ways, but roughly corresponding to Wernicke-type aphasia and Broca-type aphasia (e.g., Albert *et al.*, 1981; Bastian, 1898; Benson and Ardila, 1996; Freud, 1891/1973; Goldstein, 1948; Head, 1926; Hécaen, 1972; Kertesz, 1979; Lichtheim, 1885; Luria, 1976; Pick, 1931; Schuell *et al.*, 1964; Taylor-Sarno, 1998; Wilson, 1926). These two major aphasic syndromes have been related with the two basic linguistic operations: selecting (language as paradigm) and sequencing (language as syntagm) (Jakobson and Halle, 1956; Jakobson, 1971; Luria, 1972/1983). Jakobson (1964) proposed that aphasia tends to involve one of two types of linguistic deficiency. A patient may lose the ability to use language in two rather different ways: the language impairment can be situated on the paradigmatic axis (similarity disorder) or the syntagmatic axis (contiguity disorder).

The similarity disorder restricts the patient's ability to select words from the paradigmatic axis. These patients (Wernicke-type aphasia) cannot find words that exist as parts of the system (vocabulary). These aphasics have severely limited access to this language repertoire system. Specific nouns tend to be inaccessible and more general ones (*cat* becomes *animal*) take their place. These patients cannot select among alternative names (*dog, cat, fox*, etc). These patients may instead fill out their discourse with circumlocutions (the clock is referred as "*to know the time*"). Words no longer have a generic (paradigmatic) meaning for these patients, so verbal expressions tend to be strongly contextualized, and speech becomes empty. A "*dog*" can be referred as "*animal*", "*it barks*", "*fox*", etc.

Luria (1972/1983) emphasized that the selection disorder can be observed at different levels of the language, corresponding to different aphasia subtypes: phoneme selection (acoustic agnosic aphasia), word selection (acoustic amnesic aphasia), and meaning selection (amnesic aphasia). By the same token, the contiguity disorder can be observed at different levels: sequencing words (kinetic motor aphasia – Broca aphasia) or sequencing sentences (dynamic aphasia – transcortical motor aphasia). Noteworthy, different subtypes of Wernicke aphasia are frequently distinguished (e.g., Ardila, 2006). Luria's acoustic agnosic, acoustic amnesic, and amnesic aphasia are indeed subtypes of the language impairment syndrome referred as a whole as Wernicke aphasia.

The selection disorder

The Wernicke-type of aphasia represents the clinical syndrome characterized by impairments in the selection process (paradigmatic axis defect). In Wernicke aphasia, the lexical repertoire tends to decrease and language understanding difficulties are evident. Wernicke aphasia patients do not fully discriminate the acoustic information contained in speech. Lexical (word) and semantic (meaning) association become deficient. Patients have problems in recalling the words (memory of the words) and also in associating the words with specific meanings. It means, at least three different deficits underlie Wernicke-type aphasia: (1) phoneme discrimination defects, (2) verbal memory defects, and finally (3) lexical/semantic association deficits (Ardila, 1993).

In the Wernicke-type of aphasia obviously the language defect is situated at the level of the meaningful words (nouns). Phoneme and word selection are deficient, but language syntax (contiguity: sequencing elements) is well preserved and even overused (paragrammatism in Wernicke aphasia).

Nouns seem to depend on an organized pattern of brain activity. Contemporary clinical and neuroimaging studies have corroborated that different semantic categories are differentially impaired in cases of brain pathology. For instance, in anomia it has been traditionally recognized that naming body-parts, external objects and colors depend (and are altered) upon the activity of different brain areas (Hécaen and Albert, 1978). It has also been found that finer distinctions can be made with regard to naming defects, which can be limited to a rather specific semantic category (e.g., people's names, living things, tools, geographical names, etc) (e.g., Harris and Kay, 1995; Goodglass *et al.*, 1986; Lyons *et al.*, 2002; Warrington and Shallice, 1984) and even as specific as "medical terms" (Crosson *et al.*, 1997). A brain "mapping" of the memory organization of different semantic categories could be supposed.

The sequencing disorder

The Broca-type of aphasia represents the clinical syndrome characterized by impairments in the sequencing process (syntagmatic axis defect). It is usually cognized that Broca aphasia has two different distinguishing characteristics: (a) a motor component (lack of fluency, disintegration of the speech kinetic melodies, verbal-articulatory defects, etc., that is usually referred as *apraxia of speech*); and (b) agrammatism (e.g., Benson and Ardila, 1996; Luria, 1976; Goodglass, 1993; Kertesz, 1985). If both defects are simultaneously observed (i.e., they are very highly correlated), it simply means they both are just two different manifestations of a single underlying defect. It is not easy to understand what could be the single factor responsible for these two clinical manifestations; but it may be kind of an “*inability to sequence expressive elements*” (Ardila and Bernal, 2007). A single common factor underlying both defects should be assumed. Broca’s area, most likely, is not specialized in producing language, but in certain neural activities that can support not only skilled movements required for speech, but also morphosyntax. It is interesting to note that deaf-mute subjects (who, in consequence have never produced verbal articulatory movements) present a virtually total impossibility to learn, understand, and use language grammar (Poizner *et al.*, 1987). Probably, the lack of normal verbal articulatory development is necessarily associated with a lack of normal grammatical development.

Other aphasia syndromes

Some aphasic syndromes can eventually be considered as variants of the Broca and Wernicke aphasia. For instance, amnesic (anomic or nominal) aphasia (usually due to damage in the vicinity of Brodmann’s area 37) (Hécaen and Albert, 1978; Head, 1926; Luria, 1976) can be interpreted as a subtype of Wernicke aphasia in which the semantic associations of the words are significantly impaired.

Some other aphasic syndromes can be interpreted as language disturbances due to a more general underlying disorder. For instance, extrasylvian (transcortical) motor aphasia associated with left convexital prefrontal damage could be interpreted as an executive function defect specifically affecting the language use. The ability to actively and appropriately using the language appears impaired while the phonology, lexicon, semantics, and grammar are preserved. It does not seem difficult to argue that the ability to correctly use the language can be interpreted as an executive function and as a metacognitive ability rather than a purely linguistic ability. Some rationales

to support this interpretation are: (1) in extrasylvian (transcortical) motor aphasia there is a defect in verbal initiative rather than in language knowledge (Kleist, 1934); (2) this type of aphasia shares the general characteristics of the prefrontal (i.e., dysexecutive) syndrome but specifically with regard to the verbal processes so that it is the prefrontal (dysexecutive) syndrome affecting the verbal processes (Luria, 1976, 1980); (3) further, the language defect in extrasylvian (transcortical) motor aphasia does not affect the language understanding, and the fundamental linguistic processes are preserved (Berthier, 1999); and finally, (4) it could be argued that the prefrontal cortex does not participate in basic cognition but in metacognition (e.g., Ardila and Surloff, 2006). Extrasylvian (transcortical) motor aphasia could indeed be referred as “dysexecutive aphasia.” Some authors have interpreted extrasylvian motor aphasia in a similar way (e.g., Alexander, 2006; Luria, 1976, 1980).

Conduction aphasia, on the other hand, usually has been interpreted as a disconnection syndrome (e.g., Damasio and Damasio, 1980; Geschwind, 1965; Wernicke, 1874) usually due to an impairment in the arcuate fasciculus and sporadically in an indirect pathway passing through inferior parietal cortex (Catani *et al.*, 2005). Alternatively, conduction aphasia has also been interpreted as a segmentary ideomotor apraxia (e.g., Ardila and Rosselli, 1990; Brown, 1972, 1975; Luria, 1976, 1980).

Usually it is recognized that conduction aphasia has three fundamental (fluent conversational language; comprehension almost normal; and significant impairments in repetition) and five secondary characteristics (defects in naming; reading defects; variable writing difficulties; ideomotor apraxia; and neurological abnormalities); so-called secondary characteristics are frequently but not necessarily found in conduction aphasia (Benson *et al.*, 1973; Benson and Ardila, 1996).

This description of conduction aphasia clearly recognizes that spontaneous language production and language understanding are significantly preserved. In consequence, some mechanism required for correct language repetition is abnormal, but the knowledge of the language itself (phonology, lexicon, semantics, and grammar) is not impaired. Should conduction aphasia be interpreted as a primary aphasic syndrome? Obviously, if parrots can repeat, that means that language repetition cannot be considered as a primary linguistic ability.

Conduction aphasia is not really a primary form of aphasia but rather a secondary (or “peripheral”) defect in language affecting a specific language ability (i.e., the ability to repeat). The language itself is not impaired, but rather the ability to reproduce aloud the auditory information that is heard.

Linguistic and anthropological data: three stages in language development

The question “*When did language begin?*” could be rephrased as the question “*How did language begin?*” Different steps in language development can be proposed, at least:

- (1) Initial communication systems using sounds and other types of information – such as gestures, etc., similar to the communication systems observed in other animals, including nonhuman primates.
- (2) Primitive language systems using combined sounds (words) but without a grammar (*language as paradigm*). This type of language could be likened to the holophrastic period in language development, observed in children around 1 to 1.5 years of age (Hoff, 2003).
- (3) Communication systems using grammar (*language as syntagm*). During a child’s language development, it is observed that the use of grammar is found after the holophrastic period. It simply means that it is a more advanced and complex stage. By the end of the second year, children begin to combine words into simple sentences. Initially, sentences represent a telegraphic speech (around 24–30 months of age), including two-word utterances in which connecting elements are omitted (e.g., “*other dog*”, “*child eat*”) (Hoff, 2003). It means language initially emerges as a system of words (language as a paradigm: lexical/semantic system), and only later as a system of relations among the words (language as a syntagm: grammatical system).

Initial communication systems

It is easy to assume that at the beginning of the human language, communication systems were like the communication systems found in nonhuman primates. It is known that chimpanzees and other nonhuman primates in their natural environment can use some communication strategies.

Chimpanzees employ a variety of gestures and facial expressions to communicate and keep in touch with each other. They possess a simple repertoire of noises and postures (body language) that can be used in different contexts with specific communication purposes. Observations have been collected in different environments, including natural environments and captive groups in human-controlled environments (McCrone, 1991). Chimpanzees make use of simple gestures, make facial expressions and produce a limited amount of vocalizations. Unlike humans, chimps only produce about 12 different vocalizations. In

captive conditions and under human training, chimpanzees can learn some artificial languages and close to about 200 “words” (Cheney and Seyfarth, 1997; McCrone, 1991).

Different attempts have been made to teach nonhuman primates to use a more complex communication system. Initially, Hayes and Hayes (1952) trained the chimp Vicki. She became able to produce only four different sounds in six years! (“mom,” “pa,” “cup,” and “up”). Other chimps and gorillas have also participated in communication training programs: Nim and Koko used signs; Sara used plastic chips; Lana, Sherman, and Austion manipulated combinations of buttons to communicate (Gardner and Garner, 1979; Limber 1982; Patterson and Linden, 1981).

Regardless of the relatively large amount of meaningful elements that chimpanzees can learn, they fail in developing sequencing of elements (grammar). Kanzi learned to use around 200 symbols on a portable electronic symbol board. While chimpanzees can learn to order their symbols to get what they want, it is not clear that they have mastered syntax (Mitani, 1995; Savage-Rumbaugh and Lewin, 1994). The reason is that when they initiate communication, they often abandon the order they have learned and word order becomes random.

There have been occasional reports of chimpanzees signing new combinations of words in response to new situations. Washoe, for example, was in a boat on a pond when she encountered her first duck. She signed “*water bird*” (Terrace, 1979). This could be a new compound noun or it could be two separate responses to the water and a bird. But between two nouns, there is not a grammatical relationship and hence no grammar is involved in “*water bird*”.

In conclusion, there is not convincing evidence that chimpanzees and other nonhuman primates can learn language syntax (language as syntagm) even after intensive and controlled training.

The question becomes how this type of simple communication system found in subhuman primates in natural conditions (i.e., to use some few vocalizations, gestures and facial expressions) further developed into contemporary human language? Certain mechanisms potentially could be used, e.g., words can be created departing from onomatopias, emotional expressions, etc. Indeed, a diversity of mechanisms has been proposed throughout the history to account for how human words emerged. It means that different strategies could potentially be useful to create words. This is an ability that is not found in nonhuman primates. Using these strategies certainly requires a brain notoriously more advanced than the chimpanzee’s brain.

During the nineteenth century different hypotheses were presented in an attempt to explain the origin of language from the lexical point of view. Jespersen (1922) referred to such a hypotheses using some unusual names, as

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a way of deriding the hypotheses as simplistic speculation. However, these names became popular and they have continued to be used even in contemporary literature. Some hypotheses are (Yule, 1996):

- (1) Language began as imitations of natural sounds. It means that words are created departing from onomatopoeias.
- (2) Language began with interjections, emotive cries, and emotional expressions.
- (3) Gestures are at the origin of language and body movement preceded language. Oral language represents the use of oral gestures that began in imitation of hand gestures that were already in use for communication. Contemporarily, several authors (e.g., Arbib, 2005; Corballis (2002) have argued that gestures represent the most important element in creating human language.
- (4) Language arose in rhythmic chants and vocalisms uttered by people engaged in communal labor. Language began as rhythmic chants, perhaps ultimately from the grunts of heavy work, or related to assistance or cooperation accompanied by appropriate gestures.
- (5) Language began with the easiest syllables attached to the most significant objects.
- (6) It has been pointed out that there is a certain correspondence between sounds and meanings. Small, sharp, high things tend to have words with high front vowels in many languages, while big, round, low things tend to have round back vowels! This is often referred to as phonetic symbolism.
- (7) It has also been suggested that language comes out of play, laughter, cooing, courtship, emotional mutterings, and the like.
- (8) Considering that there is a need for interpersonal contact, language may have begun as sounds to signal both identity (here I am!) and belonging (I'm with you!).

All these hypotheses may be partially true, and all these factors may have contributed to the creation of new words. As a matter of fact, these hypotheses attempt to explain how the initial communication systems (observed in nonhuman primates) evolved to the second stage in language: the development of a lexical system, which potentially can be transmitted to the offspring. But they do not account for the development of grammar. These mechanisms for creating new words continue being useful in the contemporary world. For instance, onomatopoeias continue to represent a mechanism in the creation of new words (e.g., the ping-pong game). The phonetic symbolism is particularly useful in the creation of adjectives (qualities of the objects).

The function of noises (grunts) in human communication

No mention about the function of noises (grunts) in human everyday communication is readily available. As noted above, noises represent a basic communication strategy in chimpanzees, and noises can have continued to play a communication function throughout human history. It is evident that people in everyday life use a diversity of noises to say “yes,” “no,” to express different emotions, to communicate with animals (e.g., “come here,” “go away”), etc. These noises are close to interjections, and sometimes become real interjections (e.g., “ooph!”). Even though there is not a “dictionary” of noises, the author of this paper has been able to identify over 30 different noises commonly used in contemporary Spanish language. Some of these noises seem understandable by speakers of other languages, but others seem idiosyncratic of Spanish-speaking people. It can be speculated that these utterances /noises are only partially cross-linguistic.

Second stage: lexical/semantic

Bickerton (1990) developed the idea that a protolanguage must have preceded the full-fledged syntax of today’s discourse. Echoes of this protolanguage can be seen, he argued, (1) in pidgin languages, (2) in the first words of infants, (3) in the symbols used by trained chimpanzees, and (4) in the syntax-free utterances of children who do not learn to speak at the normal age.

It is not easy to imagine how these original words were. But the analogy with the child’s initial vocabulary can be taken: (1) They were articulatory easiest to produce, most likely using those phonemes regarded as “universal” (e.g., /p/, /a/). (2) They contained a simple syllable (consonant-vowel) that may have been repeated (e.g., *papapa*). In this regard, they were alike to the infantile words. (3) They were mostly “nouns” (real objects) even though they obviously did not have a grammatical category.

To move from grunts, onomatopoeias, and emotional expression to words, requires the progressive development of a series of oppositions. According to Jakobson (1968) the most basic one is the opposition between vowels and consonants. The second one most important is between oral and nasal articulations. But the production of these oppositions requires some anatomical adaptations.

Human articulatory ability has been related to the specific position and configuration of the larynx. The human larynx descends during infancy and the early juvenile periods, and this greatly contributes to the morphological foundations of speech development. This developmental phenomenon is

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frequently believed to be unique to humans. However, Nishimura (2003; Nishimura *et al.*, 2005) demonstrated that in chimpanzees larynges also descend during infancy, as in human infants. This descent is completed primarily through the rapid descent of the laryngeal skeleton relative to the hyoid, but it is not accompanied by the descent of the hyoid itself. The descent is possibly associated with developmental changes in the swallowing mechanism. Moreover, it contributes physically to an increased independence between the processes of phonation and articulation for vocalization. Thus, the descent of the larynx and the morphological foundations for speech production must have evolved in part during hominoid evolution and not in a single shift during human evolution.

Several authors have attempted to find universal language characteristics, and even to reconstruct extinct languages (e.g., Greenberg, 1978; Hagège, 1982; Van den Berghe 1979) such as the Indo-European (Anderson, 1973; Lehmann, 1974; Martinet, 1975; Shevoroshkin, 1990), whose last speaker passed away over 10 000 years ago. Furthermore, examples of which ones could have been the initial words in human language have been proposed. Swadesh (1971) refers to the communality existing in some words across the world. If we cannot be sure what the initial words used by humans were, there are clues about the initial meaning sounds and approximately, how the initial words may have been formed.

Third stage: grammar

What was the crucial leap for the development of grammar? (i.e., syntagmatic dimension of the language). Obviously grammar was initially simple, and “sentences” contained only two words. How to link two words to create a new higher-level unit (syntagm)? Further, how to mark the relationship between the two words? The mechanism has to be the simplest one, and it is not unlikely that it may be similar to the mechanism observed in children during language development.

Suppose that we have two lexical units:

-animal - fruit

Different relations between these two words can exist; but the relationship requires an action (verb); it means that there is an interaction between both elements: *animal eats fruit; animal has fruit, animal receives fruit; animal likes fruit*, etc.

In consequence, before creating a syntagmatic relationship between the words, different word categories have to be separated (e.g., objects and actions). According to the *Swadesh word list* (1952, 1967), the following categories are

found across different languages, and may represent the initial word categories: (1) grammatical words (e.g., I/me), (2) quantifiers (e.g., all), (3) adjectives (e.g., big), (4) human distinctions (e.g., person), (5) animals (e.g., fish), (6) highly frequent elements (e.g., tree), (7) body parts (e.g., hair), (8) actions (e.g., drink), (9) natural phenomena (e.g., sun), and (10) colors (e.g., red).

For creating a phrase, indeed only two types of elements are really required: nouns (nominal phrase) and verbs (verbal phrase). If putting together two words corresponding to two different classes (e.g., *animal sleep*), there is already a syntagm and grammar has appeared. In childhood language it is observed that words corresponding to two different classes are combined such as, “*big dog*,” “*food good*,” “*dad gone*.” They contain a grammar, because the words belong to two different classes. In the first two examples, there is an existence verb (to be) that is omitted (as currently observed in some contemporary languages, such as Russian). “*Mom dad*” is not a phrase, but “*mom big*” is a primitive sentence.

Brown (1973) found that the majority of the utterances at the beginning of the child’s grammar could be described by a small set of functional relationships between words:

- (1) “agent + action” *baby kiss*
- (2) “action + object” *pull car*
- (3) “agent + object” *daddy ball*
- (4) “action + location” *sit chair*
- (5) “object + location” *cup table*
- (6) “possessor + possession” *mommy sock*
- (7) “object + attribute” *car red*
- (8) “demonstrative + object” *there car*

So, the crucial point in emerging grammar is not the extension of the vocabulary. What is really crucial is to have words corresponding to different classes that can be combined to form a higher-level unit (syntagm). One of the words has to be a noun; the other usually is a verb.

Hence, the problem become, how verbs appeared. To create nouns does not seem so complicated using the hypothesis mentioned above (e.g., nouns can be created departing from onomatopoeias, etc). Verbs, on the other hand, can be created departing from the nouns, but with the meaning of an action (e.g., *baby kiss*). Action usually means moving, doing, executing, not simply perceiving and associating with some visual (or auditory or tactile) information. “Kiss” can be associated with some sensory information, and obviously the temporal, parietal, and occipital brain areas have to participate (*kiss* as a noun). “Kiss” can also be associated with an action, and obviously the frontal areas have to be involved in this second type of association (*kiss* as a verb).

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Brain organization of nouns and verbs

It has been observed that verbs and nouns clearly depend on different brain area activity, and naming objects and actions are disrupted in cases of different types of brain pathology. While speaking or thinking in nouns increased activity is observed in the temporal lobe, whereas speaking or thinking verbs activates the Broca frontal area (Raichle, 1994). By the same token, impairments in finding nouns are associated with temporal lobe pathology, whereas impairments in finding verbs is associated with left frontal damage and Broca aphasia (Ardila and Rosselli, 1994; Damasio and Tranel, 1993). Naming actions activates the left frontal operculum roughly corresponding to Broca's area (Damasio *et al.*, 2001). The neural correlates of naming concrete entities such as tools (with nouns) and naming actions (with verbs) are partially distinct: the former are linked to the left inferotemporal region, whereas the latter are linked to the left frontal opercular and left posterior middle temporal regions (Tranel *et al.*, 2005).

The recent discovery of mirror neurons could significantly contribute to the understanding of the brain organization verbs. A mirror neuron is a neuron which fires both when an animal performs an action and also when the animal observes the same action performed by another animal. In humans, brain activity consistent with mirror neurons has been found in the premotor cortex and the inferior parietal cortex (Rizzolatti, Fadiga, Gallese, and Fogassi, 1996; Rizzolatti and Craighero, 2004). These neurons (mirror neurons) appear to represent a system that matches observed events to similar, internally generated actions. Transcranial magnetic stimulation and positron emission tomography (PET) experiments suggest that a mirror system for gesture recognition also exists in humans and includes Broca's area (Rizzolatti and Arbib, 1998). The discovery of mirror neurons in the Broca's area might have important consequences for understanding brain language organization and language evolution (Arbib, 2006; Craighero, Metta, Sandini, and Fadiga, 2007). An obvious implication of mirror neurons is that they can participate in the internal representation of actions.

Two memory systems in language

Two major memory systems are frequently distinguished in contemporary memory literature: declarative memory (divided into semantic and episodic or experiential) and procedural memory (Tulving *et al.*, 2004). It has been suggested that the lexical/semantic and grammar aspects of the language are subserved by different neuroanatomic brain circuitries and depend upon these two different memory systems (Fabbro, 1999, 2001; Paradis, 2004; Ullman, 2001;

2004). Whereas lexical/semantic aspects of the language depend on a declarative semantic memory (knowledge about the meaning of the words), grammar depends on a procedural memory. Lexical/semantic aspects of the language (language as a paradigm) is explicitly learned, and represent a type of knowledge we are aware of (declarative memory). It depends on retro-rolandic cortical structures and the hippocampus. Grammar (language sequences, contiguity) is acquired incidentally. Procedural memory for grammar supposes implicit language knowledge. Procedural grammatical learning is related to the execution of sequences of elements (skilled articulatory acts and grammar) used for speaking but also for syntax. Procedural memory is related with frontal/subcortical circuitries (Tulving *et al.*, 2004).

Broca's area damage results in a defect in grammar and also in an inability to find verbs. In consequence, brain representation of actions and brain representation of grammar is coincidental. *Using verbs and using grammar depends upon the very same type of brain activity* and both are simultaneously disrupted in cases of Broca aphasia. It can be conjectured that verbs and grammar appeared almost simultaneously in human language; or rather, they are the two sides of the same coin. Furthermore, grammar is associated with oral praxis skills (i.e., agrammatism and apraxia of speech appear simultaneously in Broca aphasia), and hence, all three have to have appeared simultaneously in the evolution of human language: using verbs, using grammar, and rapidly sequencing movements with the articulatory organs.

Integrating aphasia, anthropology, and genetics

As emphasized above, language activity depends on two discrete brain areas (so-called Wernicke's and Broca's areas). Damage in these two brain regions results in disturbances in language as a paradigm (similarity: selection; lexical/semantic system) and syntagm (contiguity: combination; grammatical system).

At what moment in human history did the first and the second aspects of language emerged? There is not a simple answer, but obviously language as a lexical/semantic system appeared before language as a grammatical system.

Prehuman communication systems continue to play a role in contemporary human communication. Onomatopoeias continue to represent a source for the creation of new words. Noises and gesture are actively used nowadays in everyday communication.

The lexical/semantic system

Paleoneurology (study and analysis of fossil endocasts) can also significantly contribute to the understanding of the origins of the language. How did

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the brain areas participating in human lexical/semantic knowledge (i.e., temporal lobes) evolve? In monkeys, the temporal lobes are involved in recognizing the sounds and calls of the own species (Rauschecker *et al.*, 1995; Wang *et al.*, 1995; Wollberg and Newman, 1972), and obviously the temporal lobe was a crucial area in developing a complex lexical/semantic system.

Gannon *et al.* (1998) observed that the anatomic pattern and left hemisphere size predominance of the planum temporale, a language area of the human brain, are also present in chimpanzees. They found that the left planum temporale was significantly larger in 94% of chimpanzee brains examined. Hence, the crucial lexical/semantic difference between humans and chimpanzees cannot be related to the planum temporale. By the same token, it has been observed that anatomical temporal-lobe asymmetries favoring the left hemisphere are found in several Old and New World monkey species (Heilbroner and Halloway, 1988). Development of a human lexical/semantic communication system cannot be related to the temporal lobe asymmetry, because this asymmetry is observed long before the beginning of the human language.

Nonetheless, differences can be related with the temporal lobe volume. Rilling *et al.* (2002) analyzed the volume of the temporal lobe in different primates. Whole brain, T1-weighted MRI scans were collected from 44 living anthropoid primates spanning 11 species. The surface areas of both the entire temporal lobe and the superior temporal gyrus were measured, as was temporal cortical gyrification. Allometric regressions of temporal lobe structures on brain volume consistently showed apes and monkeys to scale along different trajectories, with the monkeys typically lying at a higher elevation than the apes. Within the temporal lobe, overall volume, surface area, and white matter volume were significantly larger in humans than predicted by the ape regression lines. The largest departure from allometry in humans was for the temporal lobe white matter volume which, in addition to being significantly larger than predicted for brain size, was also significantly larger than predicted for temporal lobe volume. Among the nonhuman primate sample, *Cebus* have small temporal lobes for their brain size, and *Macaca* and *Papio* have large superior temporal gyri for their brain size. The observed departures from allometry might reflect neurobiological adaptations supporting species-specific communication in both humans and Old World monkeys. The authors concluded that entire human temporal lobe and some of its component structures are significantly larger than predicted for a primate brain of human size. The most dramatic allometric departure is in the volume of the human temporal lobe white matter, which, in addition to being large relative to brain size, is also large relative to temporal lobe size. These allometric departures in humans could reflect a reorganization of the temporal lobes driven by expansion of language

cortex and its associated connections. It is interesting to note that in primates the superior temporal gyrus contains neurons tuned to species-specific calls, the magnitude of different species' relate to the repertoire of vocal communicative signals as reflections of the complexity of their respective social environments.

It has been calculated that this enlargement of the temporal lobe occurred some 200–300 thousand years ago (Kochetkova, 1973). It can thus be conjectured that hominids existing before the contemporary Cro-Magnon *Homo sapiens* could have developed certain complex lexical/semantic communication systems. For instance, it could be speculated that Neanthental man could have had a relatively complex language as a lexical/semantic system.

Brain organization of the lexicon seems to be related to the type of association between words and perceptions. When the word is associated with own-body information, brain representation of the lexicon seems associated with a parietal extension (e.g., body-part names); when the word has visual associations, an occipital extension is found (Roux *et al.*, 2006).

The grammatical system

Departing from the above observations, it can be speculated that grammar, speech praxis movements, and using verbs appeared roughly simultaneously in human history. Rather, they are strongly interrelated and depend upon a common neural activity.

Recently, a milestone observation was made that significantly enlightened our understanding about the origin of language in general and grammar in particular. In England was found a family, usually referred as the KE family. Over three generations of this family, about half the family members had presented a significant disturbance in language development. Speech was largely unintelligible, and they were taught sign language as a supplement to speech as children. Affected members presented severe disturbances in articulation and other linguistic skills, and broader intellectual and physical problems. From the genetic point of view the disorder was associated with a mutation in a single autosomal-dominant gene, FOXP2, located in the chromosome 7 (Vargha-Khadem *et al.*, 1995). The disorder was not restricted to speech and also included the following characteristics: defects in processing words according to grammatical rules; poor understanding of more complex sentence structure such as sentences with embedded relative clauses; inability to form intelligible speech; defects in the ability to move the mouth and face not associated with speaking (relative immobility of the lower face and mouth, particularly the upper lip); and significantly reduced IQ in the affected compared with the unaffected in both the verbal and the nonverbal domain.

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Further, affected family members presented a pronounced developmental verbal dyspraxia. The authors refer to the core deficit as one involving sequential articulation and orofacial praxis (Vernes *et al.*, 2006; Vargha-Khadem *et al.*, 1998). A PET study revealed functional abnormalities in both cortical and sub-cortical motor-related areas of the frontal lobe, while quantitative analyses of MRI revealed structural abnormalities in several of these same areas, particularly the caudate nucleus, which was found to be abnormally small bilaterally. An abnormal gene (SPCH1) in the chromosomal band 7q31 was localized. The genetic mutation or deletion in this region was proposed to result in marked disruption of speech and expressive language, including grammar (Fisher *et al.*, 1998).

Enard *et al.* (2002) analyzed the evolution of the chromosome FOXP2. They noted the extremely conservative nature of FOXP2. The mouse FOXP2 differs in just one amino acid from chimpanzee, gorilla, and rhesus monkey. However, human FOXP2 differs from gorilla, chimp, and rhesus macaque in two further amino acids (and thus differs from mouse in three amino acids out of 715). So, in 75 million years since the divergence of mouse and chimpanzee lineages only one change occurred in FOXP2, whilst in the six million years since the divergence of man and chimpanzee lineages two changes have occurred in the human lineage. The authors estimated that the last two mutations occurred between 10 000 and 100 000 years ago and speculate that the mutations have been critical for the development of contemporary human speech.

This genetic approach to the origins of language seems particularly provocative. Replication of the KE family genetic findings is expected in the near future.

Conclusions

Aphasia can contribute to the understanding of human language evolution. According to contemporary aphasia knowledge, in cases of brain pathology language can be disturbed in two rather different ways: as a lexical/semantic system (Wernicke-type aphasia) and as a grammatical system (Broca-type aphasia). Both language systems not only depend upon different brain areas (temporal and frontal) but also upon different types of learning (declarative and procedural) supported by different neuroanatomical circuitries. Observations of children's language development and experiments with nonhuman primates demonstrate that language initially appears a lexical/semantic system. Grammar is correlated with the ability to represent and use actions. This is an ability that depends on the so-called Broca's area and related brain circuits, but also depends, is correlated, and likely appeared simultaneously in human history with the ability to rapidly sequence articulatory movements (speech praxis).

Language as a lexical/semantic system may have appeared long before language as a syntactic system. The first one may have appeared some 200–300 thousand years ago, and may have existed in other hominids. Language as a grammatical system may have appeared relatively recently, maybe some 10–100 thousand years ago and seems to be exclusive to *Homo sapiens*.

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