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EXPLORING THE BRAIN

Lecture 11

ASPECTS OF LANGUAGE

by

PROFESSOR SUSAN A. GREENFIELD MA DPhil
Gresham Professor of Physic

27 February 1997

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Gresham College, Barnard's Inn Hall, Holborn, London EC1N 2HH
Tel: 0171 831 0575 Fax: 0171 831 5208
e-mail: enquiries@gresham.ac.uk

GRESHAM LECTURE 11: Aspects of Language
Susan Greenfield
Spring Semester 1997

Language is one of the most impressive achievements of the brain: since small children and animals are incapable of speech, some might think that all linguistic ability was the monopoly of us adult humans. However non-human animals are capable of very sophisticated forms of communication. For example, dolphins can signal over many miles: they can exchange information without harming fish, by ultrasound. Dolphins broadcast and receive these sounds simultaneously. Each 'speaks' in short phrases, with an individual whistle, like a signature.

The anatomy of all non-human species makes it impossible for them to speak words. In all these other animals, the larynx is positioned high, close to the opening of the nose. If the larynx is raised, as happens during feeding, then the non-human epiglottis and velum overlap to form a watertight seal. Hence non-human animals can breath and feed at the same time. The anatomy of the human supralaryngeal airway however is peculiar in that the larynx is positioned far lower down: a tight seal between the airways and the route to the stomach is impossible. Hence, Darwin noted as early as 1859, 'the strange fact that every particle of food and drink which we swallow has to pass over the orifice of the trachea, with some risk of falling into the lungs'. In babies, the larynx is far higher, and hence at this early stage, the human is no different from other primates. It is of paramount importance for a baby to be able to suckle and breath simultaneously. Once the larynx descends however, as we grow, there is a greater risk of choking to death, as some tens of thousand do each year. As adults, we have a restricted ability to eat and breath simultaneously. Indeed, we are 'uniquely adapted to choking to death'.

The low position of the larynx in us adult humans enables us to make non-nasal sounds. Nasal sounds occur when the nasal cavity if not sealed off from the rest of the airways by the 'velum'. Nasal sounds are misidentifed up to 50% more often than non-nasalized sounds. Hence, it is a great advantage to generate non-nasal speech. At the same time as the adult human velum is able to seal off the nasal cavity, the adult human larynx acts as a complicated air valve as its vocal cords rapidly open and close. The actual low position of the larynx enables it to act as a device that can change the steady flow of air from the lungs into a series of puffs. These puffs of air act as a rich source of acoustic energy: the rate at which they occur determines the 'pitch' of the speakers voice.

The chimpanzee airway is inherently unable to produce the full range of sounds that we humans can produce. On the other hand, chimpanzees can generate a sub-set of nasalised vowel sounds and consonants. Then again, chimpanzees (which incidentally differ in only 1% of their DNA from us), are not equipped with the complex musculature around the mouth that enables us to shape words in the refined and precise way that characterises our human abilities. Despite these limitations, there is no reason why chimpanzees nonetheless should not be able to 'speak' to some extent. But all attempts to teach chimps to talk has failed. Why? It seems that chimps use the sounds they can make in a totally different context, and for totally different reasons, compared to us. Whereas we usually use speech in an intentional and voluntary way, chimp sounds are uttered in a more stereotyped, situation, more analogous to threat and courtship gestures widespread in the animal kingdom. Although it is possible to train a chimpanzee to produce these vocalizations under different types of conditions, or to utter them with an increasing or decreasing frequency, it seems impossible for them to produce novel sounds.

Despite the problems of chimpanzee vocalisation, many attempts have been made to see whether our nearest species cousins have a linguistic ability that is not necessarily dependent on speech. Instead of training primates to talk, which as we have seen, is restricted in any event by non-human primate anatomy and physiology, there have been some notable successes, to a certain extent, in training chimpanzees to manipulate symbols, or to become proficient in American Sign Language. In such studies, although no words are being spoken, there is still a critical aspect of language needed, namely the ability to relate a concept or object to a symbol that bears no obvious physical relation to that concept or object. Working in this way, psychologists seem to have made extraordinary progress with some now famous chimpanzees. One, 'Sarah' was able to communicate that she wanted an apple for example, another that they wanted a hug. On the other hand, others have pointed out that although chimps can use symbols, and indeed become fairly sophisticated in their abilities, there is still a crucial difference between such language in non-human primates, and ourselves.

First there is the simple issue of numbers. After 4 years of intensive training, the chimpanzee vocabulary rarely exceeds some 160 words, whereas that of the human four year old counterpart is some 3,000. But perhaps the most telling difference is that chimps seem to imitate language in non-creative way. It has been argued that the truly critical difference is not so much ability, but again the context in which a chimp would use 'language'. Careful scrutiny of videos where chimps are using sign language shows that they only do so to achieve some sort of goal: the hug or the apple, for example. By contrast even very young children exhibit a spontaneity of speech that does not necessarily have a goal-directed endpoint. We are all familiar with the toddler pointing to the birds, the car , the aeroplane and so on. They do not necessarily want or need to come into contact with these objects for their immediate survival, unlike the chimpanzee counterpart. A final issue to bear in mind regarding the difference in non-human and human linguistic ability, is that the chimps using sign language have been intensively trained. Language, as we know it, namely the manipulation of symbols , oral or otherwise, does not figure in the natural repertoire of the chimpanzee, or indeed any species other than human.

In humans however, language develops naturally and spontaneously. The stages of development of language are similar in all cultures: at 6 months, there is babbling; at 1 year, one word utterances; by 18 months, words used are being used singly; at 2 years, two word utterances start to appear; six months later, at around 30 months, three word utterances in many combinations are common; by 3 years, the child is speaking in full sentences; finally, by 4 years, the young human has a linguistic ability close to that of the adult.

What is the origin of this natural ability? In most brains, as we shall see a little later, the left hemisphere has been associated with language. On the whole, this left hemisphere usually tends to be larger than the right hand side. Fossils with this asymmetry have been reported dating back some 1,000,000 years ago, at the time of *Homo Erectus.* In was at this time that it is believed that the larynx started to evolve to a lower position, along with the development of brain mechanisms for automatic speech control and voluntary mouth breathing. However the speech range would still have been limited to that of non-human primates. During the development of the ensuing generations of *Homo Sapiens* however, the vocal tract that enables the full range of human speech sounds, along with the ability to choke to death, have come into play.

One idea is that language evolved as groups in which our early ancestors lived, became larger. Primates in relatively small bands communicate by grooming, on a one to one basis. If our early ancestors started to live in ever larger packs, then clearly, one to one tactile communication would eventually prove highly time-consuming. Oral communication would reach everyone at once, as it does in the case of the stereotyped primate calls signifying the presence of threats from say birds of prey and snakes (each of which elicit a different alarm call). The benefits of spoken language are many. Another, not mutually exclusive reason for vocal communication is that it enables the hands to be freed up from gesturing, and hence of use for other activities.

It is widely known that the left hemisphere of the brain is intimately associated with language. The first evidence was actually reported in the previous century by a French physician, Paul Broca. Broca examined a patient who was incapable of articulating words: all he could say was 'Tan'. Hence, he was nicknamed 'Tan', although his real name was actually Leborgne. Shortly after Broca has documented his case, Tan died, giving Broca the opportunity to investigate his brain for any signs of conspicuous damage. Broca found a large whole on the posterior inferior temporal region of the left hand side of the brain, that now bears his name, viz. 'Broca's Area. It is now known that Broca's Area is linked to the articulation of words.

However it is important to realise that in itself Broca's Area is not the sole language centre for the brain. For example, a little later on in the nineteenth century, one Carl Wernicke reported the case of another speech deficit. This time, the patients could articulate perfectly well: however the content of their speech, and indeed their comprehension of other people's speech was markedly impaired. This region, now appropriately known as Wernicke's area is situated in the left posterior superior temporal lobe. Another type of common speech deficit, ('aphasia') is known as 'conduction aphasia'. Again damage is to the left side of the brain, but this time far from Broca's and Wernicke's areas, in the parietal lobe, which lies towards the back and top of the brain. Like patients with Broca's aphasia, patients with conduction aphasia can comprehend other people's speech, and like those with Wernicke's aphasia, articulation is normal. The problem with conduction aphasia however, is that the patient cannot name objects, nor even repeat words. This condition is often associated with an inability to coordinate the limbs and face on the right hand side of the body.

Clearly then, there is no single area of the brain devoted to speech. Rather, different aspects of the complex function of language will be divided up within the brain, and processed in different regions. The three most common aphasias have indicated three crucial areas, but even more brain regions will be called into play, depending on the precise nature of the language task at hand. The spoken word for example first processed in the auditory system with the phonological coding then taking place in the temperoparietal cortex (the area damaged in Wernicke's aphasia). From there signals are relayed to the anterior inferior frontal cortex, where sematic association takes place. This region will also be accessed by the visual system, in the case of the written word. This anterior inferior frontal cortex, as well as the visual and auditory systems all converge on the 'premotor area', which is damaged in Broca's aphasia. This area then projects to the 'motor cortex', which will eventually control the final output of language, be it speech or writing.

Although the most obvious aspects of language function are controlled by these brain regions in the left hemisphere, it is not the case that this side of the brain has exclusive control. Damage to the right hemisphere results in impairments of 'prosody'. This term refers to the emotional components of language, as well as musical elements of stress, pitch and rhythm. Hence impairments of prosody manifests as a flat tone of voice, irrespective of whether the speaker is happy or sad. In the case of damage to the right posterior region of the brain, patients do not comprehend the emotional tone of other people's speech.

Hence it is not a question of language per se being processed on the left hand side, but rather the aspects of language concerned with sensory motor processing and analytical skills. One study has shown very clearly that the issue is not so much verbal versus non-verbal, in terms of hemispheric specialisation, but rather analytical versus emotional. The study related to music students. At the beginning of their university course they were given a standard test to see what side of their brain was dominant for music. As for most people, it turned out to be the right hand side. However, after 3 years of study, the dominance pattern for music changed to, unusually, the left hemisphere. The reason for this switch has been suggested as reflecting a switch in the way the brains of the students handled music. Unlike for most of us, the three year course had trained the students to approach music with the same degree of analysis that most of us handle language.

Language then is not a single function within the brain. It is handled in a distributed fashion by many different brain regions all working in parallel. It has evolved to enable us to be freed from gestures and to produce innovative, non-stereotyped ideas and comments. As such it is perhaps one of the most sophisticated and powerful of brain functions.