

The Gestural Basis of Spoken Language

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The spoken language is perhaps one of the most important human capabilities. It is essential for the complex interactions and societies in which humans live. Frantz Fanon, the famous essayist and psychoanalyst, once said, “I ascribe a basic importance to the phenomenon of language. To speak means to be in a position to use a certain syntax, to grasp the morphology of this or that language, but it means above all to assume a culture, to support the weight of a civilization” (Fanon, 1967, p. 17). The human species is unmatched in the animal kingdom relative to the complexity of social and cultural interactions. It is what sets humans apart from the rest of the natural world. Although language is a relatively recent development in the evolution of humans, it has highly specific regions in the brain for its processing. These regions may have evolved from existing areas in the brain via natural selection; specifically regions which controlled motor movements of the arms and hands. Evidence from research done in the areas of comparative and developmental studies as well as fMRI experiments seem to reveal that vocal communication is evolutionarily as well as developmentally dependant on basic gestural communication.

The importance of gestural communication in the human species is often looked over. However, any speech or talk is always filled with gestures that go along with what is being said. Many experts in the field also agree that hand gestures allow for ideas to be conveyed in a more efficient manner than just vocally. On the speaker’s end, gestures may allow for better recollection or organization of thoughts and on the listener’s end, gestures may allow for a better comprehension of speech because of the ability to visualize as well as hear. Hauptmann (1989) conducted experiments in which he asked individuals to tell how to manipulate graphic images on a computer with either language or gestures or both. The study revealed that the individuals were more efficient and comfortable at expressing their ideas via both vocal and gestural communication than either one alone. Thus gestural communication is inherently tied to language as it not only enhances communication but also makes it more efficient.

Studies conducted with gorillas and bonobos also affirm that there is an inherent connection between gestural communication and spoken language. In Pollick and de Waal’s (2007) studies, the researchers noticed that certain hominids show use of gestural communication with the use of hands, feet, or limbs whereas other primates do not. This

implies that gestural communication is a relatively recent ability in the evolutionarily timeline. This characteristic difference is important for the further development of language because it represents a “shift toward a more flexible and intentional communicative strategy in our prehominid ancestors...[such as] a single gesture may communicate entirely different needs or intentions depending on the social context in which it is used” (Pollick et al. 2007). The experimenters wanted to test for the flexibility of the ape languages by comparing bonobos and chimps with gorillas. Since bonobos and chimps are genetically closer to humans than gorillas as well as evolutionarily more modern, the flexibility and the language capabilities may also be more developed. Observations of the ape behavior revealed that apes generally rely on gestures for communication and are more controllable than facial expressions. Thus gestures are capable of holding symbolic meaning and are able to be modified for different contextual situations for different meanings. Observations also revealed that bonobos were able to elicit more effective response from their peers when vocal and gestural communication was used than in chimps or gorillas. Bonobos also seemed to have cultural differences in the meanings of gestures whereas chimps did not. Different populations of chimps had predictable gestures and respective meanings whereas bonobos had varying pairs. Thus Pollick and de Waal hypothesized that, “Repertoire and high responsiveness to combinatorial signaling may have characterized our early ancestors, which in turn may have served as a stepping stone for the evolution of symbolic communication” (Pollick et al. 2007). Mankind’s early ancestors may have had similar traits to that of the bonobos which subsequently became more complex as the ability to vocalize and enunciate arose.

Further evidence of the evolution of language from gestural communication was discovered by Hopkins and Cantero (2003). Their comparative study of chimps and humans revealed that the lateralization of the speech centers may have dated back at least 5 million years. In humans, the Broca’s and Wernicke’s areas are known to be the language centers of the brain and are generally found in the left hemisphere of the brain. Communicative gestures have also been observed to be more dominant with the right hand than left hand and developmental data show that as infants grow, there is an increasingly preferential use of the right hand in communication. Infants who use the right hand during the early stages of life also show increased capabilities in speech. Therefore, the left hemisphere is already hardwired for handedness in communication and the preferential use of the right hand may be present in other primates. Hopkins and Cantero tested for lateralization of communication in chimpanzees by inducing communicative gestures with a banana. The chimps would make gestures for the banana and the handedness of the gesture was recorded. The researchers found that the right hand was overwhelmingly preferred in the communication than the left hand. Thus logically, there must be a deep written lateralization of communication in the chimpanzee brain just as language is lateralized in the human brain. The significance of this is profound in the sense that there was an evolutionarily push for lateralization of communication in the brain well prior to the onset of humans or their closest but now extinct ancestors. Moreover, since gestural communication as well as verbal communication is lateralized, it is reasonable to assume that the cortical areas governing gestural communication were later modified to govern verbal communication.

In order to test for the implications of the Hopkins and Cantero's research, it is important and necessary to directly look at the cortical areas which control gestures via fMRI research. Hand gestures in humans are controlled by a region of the brain called the primary motor cortex which is at the boundary between the frontal and parietal lobes, also near the Broca's area. In the macaque, the homologue to Broca's area is a region of the brain designated as the F5 region. Interestingly, the F5 region controls the macaques planning and carrying out of motor functions. Since gestural communication is a vital part of vocal communication, there must be some connection between the two processes. This connection may have been established during the evolution of the brain when the Broca's area developed from areas of the brain that controlled motor skills. Another interesting attribute to the F5 region is its mirror neurons; special neurons which are activated when an individual carries out motor action as well as when the individual witnesses a similar action. Jeannerod, Arbib, Rizzolatti, and Sakata (1995) were first to notice mirror neurons in Macaques while conducting single cell recordings in the primary motor cortex. The mirror neurons were found to be specific to the inferior frontal cortex of the monkeys' brains which controls actions of the hands and arms. The macaques were originally being studied to determine how motor neurons coded information for grasping different sized objects in the F5 region. While conducting experiments to determine how motor neurons coded for grasping objects, the team came across an interesting discovery in which they saw certain motor neurons fired when the monkeys watched someone else grasp an object as well as when the monkey itself grasped an object. The finding was very unusual because the neurons in the F5 region were not known to code for visual stimuli since they were not in the visual part of the brain. However, the fact that the macaque's neurons fired when witnessing an action as well as when it was the agent behind the action implies that there is some sort of coding for primitive understanding of actions within the F5 region.

Ferrari, Gallese, Rizzolatti, and Fogassi (2003) explored these mirror neurons further and performed more experiments on macaques; specifically their control of the mouth. The experimenters realized that there were a large number of mirror neurons specialized in mouth actions via single cell recordings. They sought out to test whether or not mirror neurons would activate for an indirect action; in other words, an action without a goal. By recording the neural activity of the mirror neurons in the two Macaque's brains during ingestive actions (direct actions), like biting an apple, and communicative gestures (indirect actions), like lip smacking, the authors were able to determine whether the specific neurons which pertained to the mouth were sensitive to indirect actions. If so, the F5 region may in fact be the beginnings of the Broca's area because of its ability to „understand“ indirect mouth actions which is an essential aspect of spoken language. Ferrari et al. (2003) found that the mirror neurons did fire during indirect actions. Macaque mirror neuron activity during communicative gestures may imply that there is a communicative basis to ingestive actions. For example, a monkey may see an intransitive action (one without a discrete object related action) and relate it to a transitive action (one that is goal oriented). Therefore, the possibility that these neurons evolved into language specific neurons is great. Over time, intransitive actions that carried meaning may have evolved into sounds and eventually into the complex language humans have today.

Further, the mirror neurons may allow for the derivation of meaning from simple tasks such as pointing, the inherent property of language. Tasks may have evolved into using facial and vocal expressions. Although the actual motor and auditory mechanisms behind speech have nothing to do with the meaning of speech, fMRI studies have shown that sound production and mouth actions are highly related to the hand motor cortex. Transcranial magnetic stimulation experiments have shown that an excited hand motor cortex actually increased reading and spontaneous speech skills. The increased rate of firing by the neurons in the region seemed to facilitate the language areas of the region in language production and processing. Furthermore, the effect only happened when the left side of the hand motor cortex was activated, the language side of the brain. There have also been experiments in which grasping actions increased syllable pronunciation; with larger objects, syllables were better enunciated. Fogassi and Ferrari's (2007) focused research further expands on the motor cortex's ability to control linguistic actions. The researchers assessed the functions of the motor cortex of the macaque as well as the motor capabilities of the Broca's areas and compared them to find similarities and to determine what functions have developed in the human brain. Comparing studies, they found that Broca's area controlled tongue and vocal actions and that the F5 region did indeed control facial movements as well as arm motions. Therefore, it is within reason to conclude that the F5 region further specialized from the control of basic arm and facial motions to the control of vocal cords. The authors also noticed that the mirror neuron system in humans is activated when humans listen or read. Thus a link between the seemingly two distinct systems had been established. In the monkey, there are motor mirror neurons which fire based on sounds and in the human, there are motor mirror neurons which help basic language capabilities.

Further evidence for the tight relationship between gestures and verbal language come from the comparative fMRI research of Sari Levanen et al. (2001). In the study, the experimenters compared cortical activations between deaf users of sign language and non-deaf subjects who did not know any sign language. Specifically, they studied the brain response of both groups while watching a video of people signing. The EEG recordings revealed that although the non-signers did not have any understanding of the sign language, they as well as the deaf group had activations in the language areas in the language areas of the brain further underscoring the gestural basis for communication. Even without any knowledge of the sign language system, Broca's and the surrounding areas were still activated because of an innate reflex to process gestures.

Developmentally, gestural communication is also vital for the comprehension and learning of language. Iverson and Goldin-Meadow (2005) conducted observational studies with infants as they progressed through their communicative stages. The researchers videotaped children between 10-24 months on a monthly basis from when they produced one-word speech to two-word combinations. They focused on the use of gestures to facilitate speech and hypothesized that gestures played a vital role in the development of the children's lexical and syntactic skills. They discovered that a child's vocabulary originated as gestures and eventually was converted to a verbal vocabulary. They also noticed that children who used gestures and words first were developmentally faster in producing two-word combinations. The dependant relationship between gestural communication and vocal

communication is further underscored by children's dependence on gestures in their early communicative stages. The findings also imply that children learn to produce and understand language via gestural communication at first much like the evolution of language from gestures to vocalization. The use of gestures may allow the child to associate meanings with words because of the double association of gestures and words with a meaning and in turn make the important task of learning language easier.

Verbal communication is an essential part of the human species and is one of the driving factors behind the species' success. However, the system through which verbal communication is processed is essentially a slightly modified version of the gestural communication system existent in mankind's ancient ancestors. As seen with comparative studies between different apes and between apes and humans, there is overwhelming evidence that gestural communication has evolved into vocal communication. Experiments with mirror neurons also reveal a progression of a specific cortical structure from the motor control of hands to the control of the vocal structures as well as an inherent ability to comprehend and understand intentions of actions. Support for the gestural basis of verbal communication is also found in the developmental studies of children and adults. Thus it is logical to conclude the spoken language not only evolved from gestural communication but still depends on it for effective communication. These findings have implications that may reach a various amount of fields as well. Linguists will be able to further understand how to communicate more effectively through incorporating more gestures. The study of autism also may be helped by these discoveries in trying to determine what the basis for the disease is. Since gestural communication is so closely tied to vocal communication, it may be interesting to see how gestural communication is affected in those with autism. These are just a few applications and with a greater understanding of relationship between speech and gestures via evolutionary and developmental studies, the possibilities are endless.

References

- Bates, Elizabeth, and Frederic Dick. "Language, Gesture, and the Developing Brain." *Developmental Psychobiology* 40 (2002): 293-310.
<<http://www3.interscience.wiley.com/cgi-bin/fulltext/91013412/PDFSTART>>.
- Ferrari, P. F., Gallese, V., Rizzolatti, G., & Fogassi, L. (2003). Mirror neurons responding to the observation of ingestive and communicative mouth action in the monkey ventral premotor cortex [Electronic version]. *European Journal of Neuroscience*, 17, 1703-1714.
- Fogassi, L., & Ferrari, P. F. (2007). Mirror neurons and the evolution of embodied language [Electronic version]. *Current Directions in Psychological Science*, 16 (3), 136-141.
- Hauptmann, Alexander G. "Speech and Gestures for Graphic Image Manipulation." ACM (1989): 241-245. 28 Apr. 2008 <<http://lastlaugh.inf.cs.cmu.edu/alex/chi89.pdf>>.

- Hopkins, William D., and Monica Cantero. "From Hand to Mouth in the Evolution of Language." *Developmental Science* 6 (2003): 55-61. 28 Apr. 2008 <<http://www.blackwell-synergy.com/doi/pdf/10.1111/1467-7687.00254>>.
- Iacoboni, M., Molnar-Szakacs, I., Gallese, V., Buccino, B., Mazziotta, J. C., Rizzolatti, G. (2005). Grasping the intentions of others with one's own mirror neuron system [Electronic version]. *PLoS Biology*, 3 (3), 529-535.
- Iverson, Jana M., and Susan Goldin-Meadow. "Gesture Paves the Way for Language Development." *American Psychological Society* 16 (2005): 367-372. 28 Apr. 2008 <<http://www.blackwell-synergy.com/doi/pdf/10.1111/j.0956-7976.2005.01542.x>>.
- Jeannerod, M., Arbib, M. A., Rizzolatti, G., & Sakata, H. (1995) Grasping objects: the cortical mechanisms of visuomotor transformation [Electronic version]. *Trends in Neurosciences*, 18 (7), 314- 320.
- Levanen, Sari, Kimmo Uutela, Stephan Salenius, and Riitta Hari. "Cortical Representation of Sign Language: Comparison of Deaf Signers and Hearing Non-Signers." *Cerebral Cortex* 11 (2001): 506-512. 28 Apr. 2008 <<http://cercor.oxfordjournals.org/cgi/reprint/11/6/506>>.
- Pollick, Amy S., and B. M. De Waal. "Ape Gestures and Language Evolution." *PNAS* 104 (2007): 8184-8189. 28 Apr. 2008 <<http://www.pnas.org/cgi/reprint/0702624104v1>>.
- Rizzolatti, G., & Arbib, M. A. (1998). Language within our grasp [Electronic version]. *Trends in Neurosciences*, 21 (5), 188-194.
- Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system [Electronic version]. *Annual Review of Neuroscience*, 27, 169-192.
- Rizzolatti, G., Fadiga L., Gallese, V., & Fogassi, L. (1995). Premotor cortex and the recognition of motor actions [Electronic version]. *Cognitive Brain Research*, 3, 131-141
- University of Alberta (2005, May 11). Hand Gestures Linked To Better Speaking. *ScienceDaily*. Retrieved April 28, 2008, from <http://www.sciencedaily.com/releases/2005/05/050511105253.htm>