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A Neurolinguistic study on communicative gestures and developed speech

Abstract:

This paper looks to make an evolutionary connection between the communicative gestures of chimpanzees and the human development of speech. In so doing, the connection between brain size and speech abilities is explored with a particular focus on genetic and gene expression, rejecting the oft-stated hypothesis that humans are capable of speech due to a larger brain size and instead embracing the argument that an increase in diversity of genetic expression is likely to be more responsible for this phenomenon. In so doing, the author looks at previous work regarding the speed of evolution and how said speed differs depending on the magnitude of evolutionary changes which occur. Finally, the paper explores the role of mirror neurons in speech and proposes future research in this area, based on questions regarding how neural stuctures are organized and how they develop within chimpanzees over their lifespan.

Keywords: development; evolution; genetics: gestures; neurons: speech

The ultimate goal of this paper is to demonstrate that there is a clear evolutionary line from chimps having developed communicative gestures to the human development of speech. In so doing, this paper postulates that the primary distinction between chimps and humans that prevents the latter from developing speech is their smaller brain size coupled with a shorter lifespan and correspondingly shorter time frame for maturation. This would be done within an Evo-Devo framework which probes how systems evolved and what the consequences of the evolutionary process has been (Muller 2007).

Utilizing chimpanzees for comparison is an apt choice. Studies going as far back as Pilbeam (1986) have urged that, from a genetic and evolutionary standpoint, chimpanzees are the closest relatives human beings have (see also Bailey 1987 at 441: Olson and Varki 2003)- closer, for example, than gorillas to human beings. Therefore, this paper focuses on chimpanzees rather than apes or gorillas.

Science and logic supports the notion that communicative gestures precede human speech. After all, as Arbib, Liebal and Pika (2008) note, gestural communication precedes vocal communication in human infants and adults. Furthermore, even when they have gained the ability to verbally express themselves, humans continue to use co-speech gestures. Complementing this finding is earlier work (Hewes 1973) which indicates that man's first language was gesture based, rather than vocal. Additionally, there are numerous languages which do not involve using words: not just sign languagesbut also those, to pick just one example, which are based entirely on whistling, such as the Kuskoy, which is used in a remote Turkish village and el Silbo which can be found on Isla de la Gomera which is one of the Canary Islands just off the Moroccan coast (Bohlen and Rinker 2005). Although information is hard to find, these languages appear to have pre-historic origins (Thomas 1995), a stark contrast with spoken languages[1]. This timeline would bolster our hypothesis that chimps developed gestures and then human beings developed speech by adding to it: humans develop gestures, then speech, then language. This works on an individual scale as well: humans can imitate facial and manual gestures before they are even a month old (Meltzoff and Moore 1977), segue from gestures to babbling around the age of six months (Wein 2007) and learn to speak thereafter, their speech

[1]For instance, English language originated by having Germanic language introduced to Britain in the 5th Century. (Blench and Spriggs Eds., 1998: 286)

improving as they age and by eighteen months they can speak eight to ten words (Wein 2007) and are able to communicate in multiple ways- i.e. speech and gesture- simultaneously.

The need for outlining an evolutionary journey from communicative gestures to the human development of speech is underlined by studies such as Steele and Uomini (2009) which seeks more information for how speech and language processes evolved from manual gesturing. This paper makes no claims that it will be a definitive last word on the subject. The aim is to advance the conversation.

1. Chimps, Humans and Communicative Frameworks

Chimps and humans are not terribly different. As a matter of fact, Britten (2002), using chromosomal sequencing, estimated that chimps and humans share 95% of all base pairs of our respective DNA sequencing. Additionally, Pilbeam (1986) pinpointed chimpanzees as being "most similar" to human beings when looking at DNA profiles.

One of the greatest differences between chimps and humans, from a biological standpoint is that the human cerebral cortex is three to four times larger than the cerebral cortex of chimpanzees (Bailey 2005). With regards to our communicative abilities, it has been shown (Taglialatela, Russell, Schaeffer and Hopkins 2008) via brain imaging research, that when chimps gestured and called out for food the brain regions which showed activation corresponded to where Broca's area is in humans. Broca's area is the part of the brain long thought to be responsible for speech production (Broca 1861).

In their work, Taglialatela, Russell, Schaeffer and Hopkins (2008) noted that Broca's Area was located in the inferior frontal gyrus in the brain and that when chimps communicate portions of their brain corresponding locationally to Broca's Area becomes activated. In their study, Taglialatela, Russell, Schaeffer and Hopkins (2008) had used captive born chimpanzees between the ages of fourteen and eighteen and subjected them to a PET and an MRI study. It is unclear how the researchers could have observed gestures with subjects in an MRI machine. However, a PET is a different story. With a PET scan, subjects are administered a radioactive substance either through inhalation or ingestion or injection which emits a positron that annihilates in a collision course with an electron. Subsequent to such annihilation two photons travel in different directions and if this event is detected it is recorded. (Ollinger and Fessler 1997). Given the above, it is entirely possible to use PET to measure such activations in the brain and theoretically it should be viable in testing on chimpanzees as well.

Additional work on this subject by Taglialatela, Russell, Schaeffer and Hopkins (2009) found that chimpanzee brains are activated in response to some calls but not others. In their work, they once again used PET. In the 2009 study, they had three subjects participating in three separate PET scanning sessions. The responses were shown to be limited to broadcast conspecific vocalizations (BCVs) and proximal conspecific vocalizations (PRVs). The BCVs included sounds such as pants or hoots: PRVs had grunts and barks. A third category, TRV (time reversed vocalizations) included a mixture of the previous stimuli. It was this group [the TRVs] that the chimpanzees were least responsive to. The authors concluded that there were “neural correlates of auditory perception in chimpanzees”. As such, it stands to reason that fundamentally, chimp and human brain anatomy is substantively similar since they produce such similar responses to certain stimuli. Indeed, it has been argued by some (Povinelli and Vonk 2003) that brain size has been one of the key changes as humans evolved from chimpanzees and some earlier research, such as Aiello and Dunbar (1993) has contended that a need for large primate groups drove both the evolution of language and the growth of the human brain. However these earlier researchers did not delve deeply into the mystery of brain size.

Brain size is not merely a matter of fate, but rather one of genes and as such those who argue that brain size is the crucial determiner for the development of speech are superficially right yet, on a deeper and more scientific level, wrong, inasmuch as they see the result- brain size- without seeing the source- genetic changes leading to larger brain size. Evans, Anderson, Vallender Choi and Lahn (2004) have shown that at least one specific gene, the microcephalin gene, controls brain size.

In their paper, Evans, Anderson, Vallender Choi and Lahn also demonstrate that the growth of the cerebral cortex in humans and its size relative to chimpanzees was due to a protein sequence that evolved from simians to humans. Specifically, the authors point to forty-five beneficial changes in amino acid composition which took place over about thirty million years of evolution resulting in brain expansion in humans. They specifically link ASPM as the gene responsible, along with the evolutionary trait of positive selection to this expansion in brain size.

[Positive selection refers to genetic alterations which allow the beneficiary to adapt better to their environment[2].]Zhang (2003 a) defines the ASPM (abnormal spindle-like microcephaly associated) gene as one that went through a mutation and acceleration immediately after humans and chimpanzees split but before Africans and non-Africans started their separate development. As Evans, Anderson, Vallender Choi and Lahn (2004) note, those humans in whom this gene sequence does not develop properly are afflicted with microcephaly, which is a condition where brain size is severely reduced. Additionally, Fisher and Marcus (2006) pinpoint a number of genetic sequences that aid speech:

Table 1: Genes associated with brain size: (Fisher and Marcus 2006)

Gene	Role in brain development
REFS 134	Controls brain size
REFS135	Controls brain size
MCPH1	Responsible for encoding microcephalin
ASPM	Gene which, in null form, causes microcephaly

Fisher and Marcus (2006) also provide a table for which genes have been implicated in different language based disorders such as SLI. What's notable about this data is that MCPH and developmental verbal dyspraxia[3] are the only disorders which implicate the SPCH1 and the MCPH family (one through five) gene sequences. As noted before, MCPH1 is responsible for controlling brain size. Portions of the SPCH1 gene, specifically 7q31-33 have also been linked to autism (Tamiji and Crawford 2010), another expressive disorder.

With this in mind, it's prudent to look at two issues: gene maturation and the presence or absence of expressive genes in chimpanzees.

[2]An example of this is how bitter taste selection via the bitter taste receptor (T2R) genes prevents cows and dogs from ingesting harmful substances. (Zhou, Dong, Zhang and Zhao 2009).

[3] An expressive disorder characterized by a difficulty in speech production and sequencing. (Williams 1998) Note that comprehension is not impacted.

2. Gene Maturation

The sub-thesis of this paper- complementary to the overall proposition advanced in the preamble is that chimpanzees have a shorter period for maturation- is that genes and brains mature over time both in humans and chimpanzees and they do so at the same rate. Evidence for the existence of the process of brain maturation can be found in Herndon, Tigges, Anderson, Klumpp and McClure (1999). First, the Herndon team found that the maximum lifespan of female chimpanzees[4]was fifty-nine yearswith males coming in at forty-five years. Other studies, like Lang (2006) second the forty-five year figure and note that chimps have a longer lifespan in captivity. By contrast, human life expectancy is tremendously varied but is nearing eighty for those born in the United States (Arias 2004) This lends superficial support to the sub-thesis mentioned at the beginning of this paragraph that chimpanzees have a shorter time period for gene maturation.

However, Duscheck (2011) notes that after the age of thirty humans begin to age noticeably and that starting at the age of thirty five lose one hundred thousand brain cells per year. Clearly then, a longer lifespan is not necessarily a boon to humans. The question is whether, the sub-thesis still holds: like humans, chimpanzees also age. However, Herndon, Tigges, Anderson, Klumpp and McClure (1999) found that chimpanzees under the age of thirty had larger brains than those over thirty. What this means is that chimpanzees who die earlier mature at the same ages- and therefore mature more slowly. In a nutshell, if a human lives until 80 and a chimp until 59, the human lived thirty-five percent longer. Therefore, if a chimp starts losing brain mass at 30, a human should theoretically start the same loss thirty-five percent later in life, at the age of 40 and a half. However, this is not the case. For this reason, the sub-thesis that gene maturation takes place at the same rate in both species is rejected. [But not the principle that said maturation takes place.] This has the potential to pose a certain peril for our overall theory that there is an evolutionary line between primate gestures and the development of human speech. Let's see if it survives!

3. Brain Matter in Chimps and Humans

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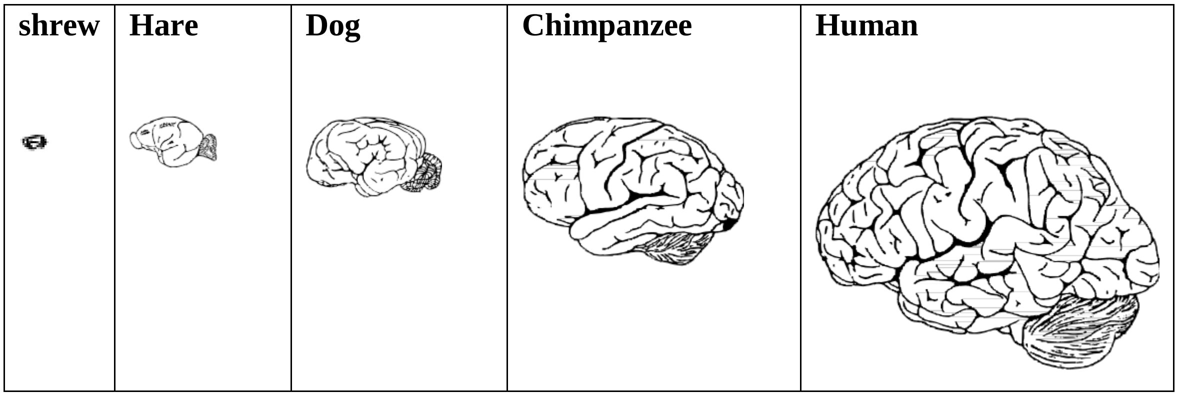
[4]The chimpanzees were raised in captivity with ample food and health care. As such, the life spans presented here are perhaps the highest possible for chimpanzees.

Below is a figure taken from Roth and Dicke (2005) showing the brain sizes of certain mammals in absolute terms.

Figure 1: Mammalian Brain Sizes in Relation to Each Other



(Note that the original figure also showed whales but space limitations forced it to be removed.)
As can be seen from the above figure, the brain of a chimpanzee is considerably smaller than that of a human being, and as noted before, Bailey (2005), among others, affirmed one of the underpinning of this paper that the biggest difference between chimps and humans when it comes to their brains is size. Looking at the chimpanzee brain and the human brain one can see many structural similarities, such as the presence of a cerebellum. Additionally, one can also see that the chimpanzee cerebellum is much smaller than the human one. But is it simply a question of scale? In short, the answer is no.

Scale does not affect all parts of the chimpanzee and human brain equally. Even though the chimpanzee brain is smaller overall, not all components of it are smaller than corresponding components in humans. Blakeslee (1998) chronicles how research has found that out of the eighteen chimp brains studied, seventeen "had enlarged plana temporale on the left side of the brain." Broadly speaking, the plana temporale deals with language which led some, like Gannon, Holloway, Broadfield and Braun (1998) to hypothesize that since the plana temporale contains Wernicke's area which is instrumental to understanding language, chimps may have, at least at one time, been able to understand language. In the same language-ready vein, Genova (2008) reported that the area of their brain that would correspond to Broca's area in the human brain was activated when they made gestures and noises while seeking food out of their reach. As such, there is considerable appeal to the idea that chimpanzees are language ready primates- people on a small scale. Alas, they are not.

4. Gene Expression

What those who may be seduced by the brain size argument[5] do not take into account is the differences in gene expression between chimpanzees and humans. Gene expression refers to a biological process where the information encoded within genes nestled on DNA strands is transformed into proteins. (Rueter 1996) If this transformation does not take place or does not take place in an appropriate manner, the result could be disastrous: it's like having the components for a car ready yet assembling them improperly.

The degree of gene expression differs considerably between chimpanzees and humans with humans expressing far more genes in their brain than chimpanzees do. (Gu and Gu 2003) Specifically, Gu and Gu found the most striking patterns to emerge when looking at gene diversification expression patterns. Diversification is as it sounds, the many different ways in which genes can combine to express themselves. Gene diversification is considered an evolutionary necessity: the more gene diversification occurs, the better the chances for a specific species to survive (True and Carroll 2002: 61) One can logically assume that this is the reason incest is frowned upon in human societies- incest has the potential to copy and expand the influence of bad genes while suppressing the possibility of having new genes enter the bloodline- a combination which lessens the prospect for the offspring to survive (Mosher 2008) Considering the benefits of gene expression diversification, it stands to reason that a species would do better if it had more of it- the implicit point of Mosher (2008) and so the chimpanzees analyzed by Gu and Gu (2003) are at a definite disadvantage. According to Gu and Gu (2003), human gene expressions are 2.77 times more diversified than the gene expressions of chimpanzees. [And 5.21 times more diversified than the gene expressions of orangutans.] Additionally, it has been found that gene expression patterns tend to not be uniform, but rather are far more pronounced in the central nervous system and the cerebral cortex of human beings and chimpanzees than they are in other organs such as the liver (Olson and Varki 2003). Thisgives additionally ballast to our original decision to focus on chimpanzees and humans as opposed to another primate such as the gorilla[6].

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[5] As this author initially was.

[6] This marked difference may explain why neurological ailments such as Alzheimer's are far more common in humans than gorillas. It has been shown (Pimm 1984) that when there are more species in an ecological community, that community is less resilient and stable. A variant of the same principle may hold sway here- that the more parts and functions an organism has, the more

Given the foregoing, the previous debate about brain size and the previous assumptions about the differences in maturity and life expectances between chimpanzees and apes can be reduced in importance: after all, having considerably more time to grow genetically and physically does not matter much if the genetic growth simply does not take place. However, there may well be a bridge between the two groups as we shall see. And of course, the author still maintains that there can indeed be a clear evolutionary line from chimpanzees developing gestures to the human development of speech.

4.1 The FOXP2 Gene in Humans and Chimps

There is one gene not mentioned thus far that is so important it deserves its own section in this paper, namely the FOXP2 gene. It has been saved for this section because its impact on expressive speech serves as a bridge between those who consider brain size to be crucial and those who are more strongly inclined to look at genetics as the determiner of why chimpanzees, despite all their similarities to humans cannot express themselves verbally.

The two positions are not irreconcilable. It is reasonable to argue, as King and Wilson (1975) did in a groundbreaking paper that miniscule genetic changes led to physiological changes. This is so because changes in amino acids can alter proteins which in turn can alter genes. Additionally, even if a gene is unchanged its location still might shift for any number of reasons, such as the addition or deletion of certain specific parts in a sequence. In fact, it is likely that this happened: King and Wilson (1975) hold that there is “a parallel between rate of gene rearrangement and rate of anatomical evolution” when it comes to mammals. In other words, genes and how they are expressed have a physiological impact. As such, one can say that brain size was due to genetic changes and therefore both have a role in why chimpanzees are incapable of speech.

As Bryson (2003: 3) so memorably puts it “The average species on Earth lasts for only about four million years, so if you wish to be around for billions of years, you must be as fickle as theatoms that made you. You must be prepared to change everything about yourself—your shape, size color, species affiliation, everything—and to do so repeatedly.” This observation is at the

susceptible it may be to a breakdown. However this observation is just an aside rather than a new track in a paper that already has quite enough to discuss.

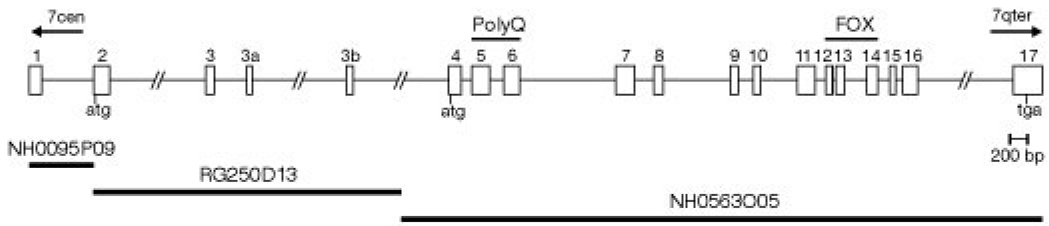
core of Evo-Devo: essentially, the field and this paper is aimed at probing the nature of our successful fickleness.

Bryson's point is borne out by synthesizing later research. For example,research (Zhang 2003 b) found that certain genes, most notably olfactory-receptor ones, have been deactivated in humans simply because we no longer need them. What's more, Wilson, Bush, Case and King (1975) point out that social structures in a population might promote re-arrangement in genes. This is a logical argument. When considering Wilson, Bush, Case and King (1975)'s point in light of research by Wallace (1957), that small genetic changes can lead to significant physiological changes-we can conclude, as Gilad, Man, Paabo and Lancet (2002) did that the reason so many olfactory genes have been deactivated in humans unlike in of chimpanzees and apes is because humans do not need their sense of smell the way apes and chimpanzees, who use olfactory senses for social purposes, such as sniffing out a potential mate, still do. As such, Gilad, Man, Paabo and Lancet (2003) show that in humans olfactory genes have been deactivated at a rate four times that of monkeys. This deactivation is a negative change and it confirms Wallace (1957)'s contention that most genetic mutations are negative in nature. [The author considers the deactivation of olfactory genes to be negative in the sense that by said deactivation, takes away a specific ability: Wallace (1957), asserts that "Geneticists are nearly unanimous in their belief that the vast majority of mutations are deleterious."[7]]

Of course, genetic mutations can be beneficial and socially necessary as well. In their work, Fisher and Marcus (2006), specifically note that the FOXP2 gene is both possibly responsible for the development and functioning of circuits throughout the brain, as well as being "highly conserved in vertebrates". Fisher and Marcus (2006) conclude by noting that after humans split from chimpanzees, the FOXP2 gene "underwent accelerated coding change". What does this mean? To understand this phenomena better, a visual representation of the FOX P2 gene (Lai, Fisher, Hurst, Vargha-Khadem and Monaco, 2001) would be helpful:

Figure 2: The Human FOX P2 Gene

[7]Deleterious is defined by dictionary.com as injurious or harmful.

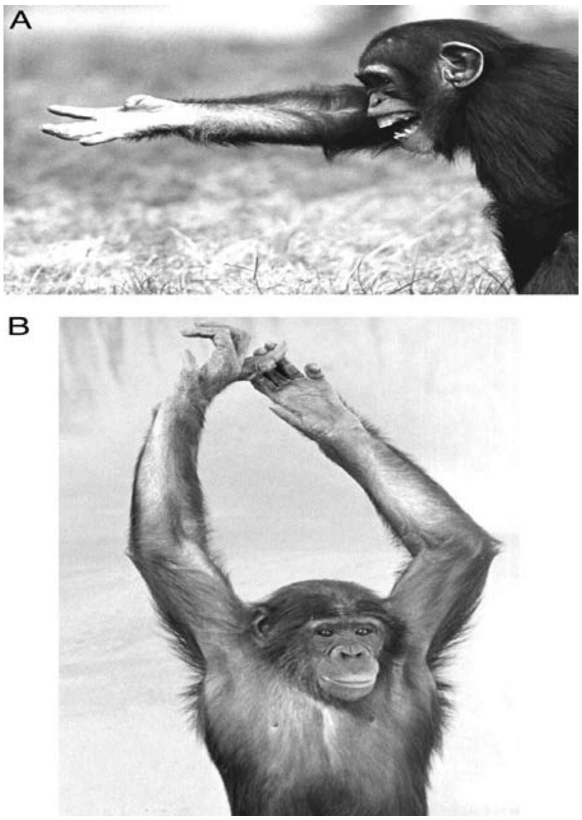


As can be seen, the FOX P2 gene lies within Chromosome 7: when damaged, Chromosome 7 can cause a number of ailments, many of which are related to one's ability to express language. These include Greig cephalopolysyndactyly syndrome where one's face (and limbs) may not develop properly and Saethre-Chotzen syndrome when the skull can't grow normally because of premature fusion of the skull bones. As for the FOX P2 gene itself, it clearly affects linguistic capabilities (Harvati 2010) and mutations to it cause speech impairment and deficits in linguistic skills (Fisher and Scharff 2009). Thus, it stands to reason that if the FOX P2 gene is affected, the ability to speak is also impacted. In fact, in her work, Harvati (2010) claims that Neanderthals like modern men, had a variant of the FOX P2 gene but because it was not sufficiently mature it did not provide them with the ability to express themselves through modern speech. This claim is bolstered and expanded upon by Harding and McVean (2004) who themselves suggest that the FOX P2 gene was a target for positive selection so that humans may become more proficient at speech than their predecessors. Therefore we can see that the FOXP2 gene increased in strength and importance as modern humans evolved. This scientific background assists us in the second part of our journey, towards speech: but we must also look at our communicative beginnings, gestures.

5. Gestures as a Precursor to Speech

In order for the theory that chimpanzee development of gestures preceded and can be directly linked to human development of speech to succeed, gestures must have developed in chimps before speech did in humans both on an individual level and a group level. The second part of this theory is not controversial: it is widely accepted that humans split off from apes millions of years ago (Wadhams 2007) and that human beings and chimps went their separate evolutionary ways over six million years ago (Brown 2006). It has also been shown that individual chimpanzees are capable of meaningful gestures rather than just simply waving their limbs aimlessly. (Pollick and de Waal 2007) Pollick and de Waal studied captive chimpanzees and bonobos- a total of forty-seven subjects- and found that both groups were capable of using facial expressions as well as vocal and manual signals, the latter being, in part, gestures.

Figure 3: Chimpanzee (A) and Bonobo (B) Gesture (Pollick and de Waal 2007)



In the above image, in part A, a chimpanzee is reaching out and making a begging gesture while screaming at a dominant member of the tribe who took his food away. In part B, an adolescent bonobo is making a sexual gesture.

How are these classified as gestures rather than as aimless rants or movements? Pollick and de Waal (2007) narrowly define a gesture as a form of nonverbal communication. Others, like Leavens and Hopkins (1998) look at gestures in chimpanzees as having a nexus between a need and a feasible way to sate that need: for example, they count pointing at food objects as a gesture and so was banging the cage since both acts had communicated a need. This definition of a gesture has not often been applied to humans. In the human realm, defining gestures have often focused on the hands. As one writer said “For other portions of the body merely help the speaker, whereas the hands may almost be said to speak. Do we not use them to demand, promise, summon, dismiss, threaten, supplicate, express aversion or fear, question or deny?” (Butler and Quintillian 1922: 289 as cited by Kendon 2004: 18)

However, evidence suggests that a broader definition of gestures is required from a practical standpoint. If a gesture is an expression of need, then there are multitudes of ways for creatures to express themselves be they human or animal and of course they have a multitude of needs to express. Other realms have already recognized such. For instance, the Illinois Appellate Court, in a decision from 1989, noted that the trial judge “slammed down his pencil, heaved a sigh and made facial gestures in response to a question posed by defense counsel.” Later on the Court opinion noted that these non-verbal gestures, far from being meaningless, may have been communicative in nature and may have conveyed an impression of guilt to the jury (Goldenhersh 1989). Thus it is prudent to define human gestures as a physical, non-speech based expression of need.

Do chimps also have these gestures at their disposal? Are they able to purposefully make faces, sigh and throw items around not without purpose but in a communicative context? Evidence is hard to come by- after all, we can’t very well ask a chimp to tells us if he is gesturing and people are sometimes blind to each other’s gestures, never mind those of another species, but researchers like Boehm (1992) refer to chimpanzee vocal interactions as having characteristics which can be fairly labeled conversational in nature, whilePollick and de Waal (2007) imply that the answer is affirmative. In their study, they used staring, grunting, biting and fleeing as possible gestures because they fell into certain behavioral categories that represented certain needs- such as the need to affiliate, to play, to eat and to engage in sexual expression. In summary, gesturing can be described as a non-word-based expression of need, made not randomly but with a purpose and one that humans and apes are both capable of.

When did chimpanzees develop the ability to gesture? This is a harder question and one that needs to be broken down to look at both groups and individuals. Individual chimpanzees, who, remember, have an optimal lifespan of about forty-five years in the wild (Herndon, Tigges, Anderson, Klumpp and McClure 1999: Lang 2006), begin developing gestures at the age of one, gain more confidence and use gestures outside of their family and peer group by the age of two and are able to coordinate gestures and gaze by the age of three (Tomasello, George, Kruger, Jeffrey and Evans 1985). By contrast, human babies can imitate facial and manual gestures as soon as twelve days after they are born (Meltzoff and Moore 1977)

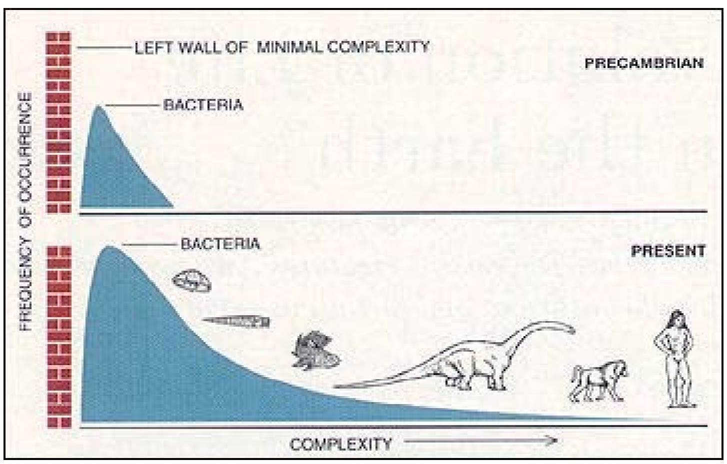
6. The Evolution of Gesturing in Chimpanzees

It is a lot harder to trace when chimpanzees as a whole began to develop the ability to gesture. We do know that chimpanzees originate from Africa (Pilbeam 1986), however evidence beyond that is difficult to assess. Some, like Fay and Carroll (2005) point to central Africa with Fay and Carroll (2005) refining their point of origins further to the southwestern tip of what is today the Central African Republic, based on archeological findings related to tool use but there is not a great deal of external evidence in support of same. Additionally, even if the location of chimpanzees can be traced accurately, their behavior is far more difficult to trace.

6.1 From Appendages to Limbs

Because it is difficult to trace how and when chimpanzees precisely learned to gesture, Evo-Devo scientists have taken a different tack, looking at the evolution of appendages. It is commonly accepted that the first living organisms on Earth were simple clay crystals (Cairns-Smith 1985). From that point forward, life on Earth moved forward in spurts with extremely long periods from one change to the other with more complicated evolutionary changes taking place far, far less frequently. Below is an excellent illustration of this frequency rule, from Gould (1994)

Figure 4: Pace and Complexity of Evolution- an Inverse Relationship



As we can see, bacteria occurred appeared far more often than more complex organisms. In a nutshell, complex evolutionary changes take time and tend to be rare affairs. Simplicity rules: to this day, the simplest life form- bacteria- is also the most enduring and successful. As an illustration of this rule, note that while there are seven billion human beings on Earth, back in 1998 it was found that five million trillion trillion individual bacteria existed. (Science Blog, 2004). A further illustration might be that while there are more than one point seven million species of life on Earth, from mushrooms to mammals (Osborn 2011), there are a grand total of six species-three mammals and three birds- that are capable of vocal communication (Jarvis 2004) and of course only one which is capable of human speech. This may go back to the variant of the Pimm (1984) proposed in footnote six of this paper: Just as having more species in an ecological community, makes that community less resilient and stable, and having more parts and functions may make an organism more susceptible to breaking down, it may be that the more complex evolutionary changes occur in an organism, the more susceptible that organism is to breaking down. Evolution is a risky business.

6.2 Mirror Neurons

Given the demonstrated rarity of large evolutionary leaps (Gould 1994), it makes sense to propose a theory that starts small. Hence, we begin with gestures in chimpanzees. The idea that speech evolved from gestures is supported by Corballis (2003), who hypothesized that the activation in what should be Broca's area in chimpanzee brains when they are gesturing- a scientific finding of Taglialatela, Russell, Schaeffer and Hopkins (2008) which the Corballis theory precedes- was due not to vocal control but the presence of mirror neurons which coded for the production and perception of gestures. Mirror neurons are hypothesized to help monkeys as well as possibly humans observe the actions of another and mimic or respond to the same (Gallese and Goldman 1998). These neurons are generally found in the premotor cortex of monkeys as well as the posterior parietal cortex, the latter of which generally corresponds to Brodmann's Area 7 (Miall 2003)- an area of the brain which helps humans in the task of visual-motor coordination. In monkeys, they perform much the same function, allowing them to spot bananas and then grasp them.

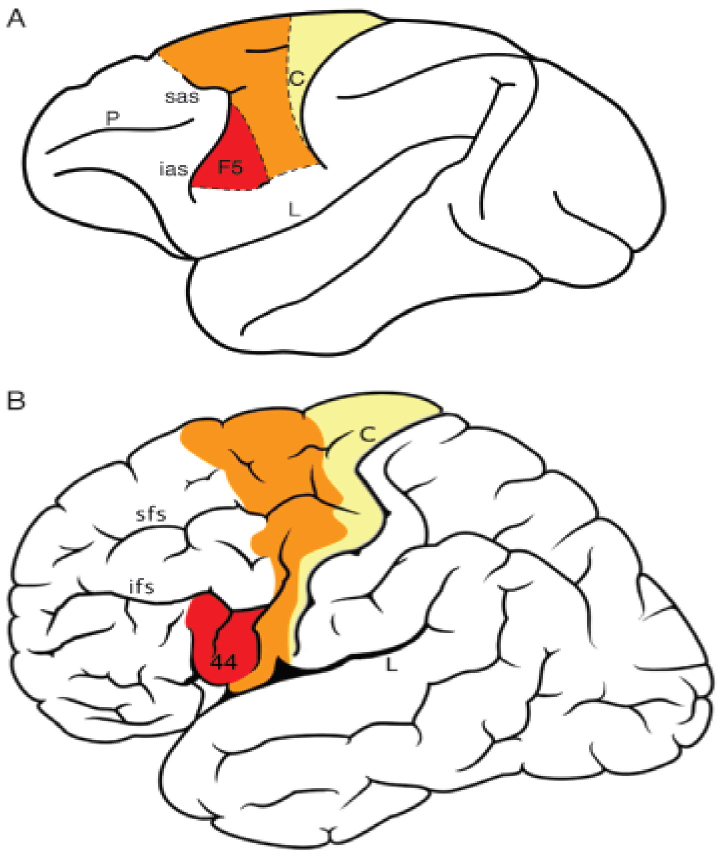
Recall that we earlier examined how monkey brains and human brains have certain structural similarities (See **Figure 1** of this paper and note the visual similarities: information from Roth and Dicke 2005). Given these similarities, it should not be surprising that humans and monkeys both share mirror neurons and that they may have similar functions. However this is not merely about mindless mimicry. Rather, the use of mirror neurons is quite precise, taking into account intent as well as method. For example, monkeys will mimic humans and monkeys grasping objects but not a robot doing the same or the use of pliers. (Miall 2003) Thus we can draw the inference that monkeys, like humans, understand the act, the actor and the context it occurs in. This is not surprising, for monkeys are capable of meaningful gestures that communicate a specific need (Pollick and de Waal 2007) and so it stands to reason that monkeys can not only give meaning to their own gestures but can draw meaning from the gestures of others.

Because monkeys utilize gestures in proper contexts (Miall 2003) and do so with specific goals informing their choice of gestures (Pollick and de Waal 2007), this bolsters our theory that chimps developed not just gestures but communicative and meaningful ones and that said gestures evolved until, in humans they grew into the development of speech. Mirror neurons were crucial in this transition. It has been hinted (Fadiga, Craighero, Buccino and Rizzolati 2002) that mirror neurons are activated in humans when they speak: however evidence on this front is not conclusive and researching this is a promising area for future work. We do know that mirror neurons organize into elaborate systems in humans for the purpose of social theory of mind functions and that autistic individuals may be suffering from a failure of these mirror neuron systems to function properly (Williams, Whiten, Suddendorf and Perrett 2001).

This finding fleshes out our theory to some extent: We can now say that the evolutionary line from chimps having developed communicative gestures to the human development of speech is accompanied not only by genetic developments but the development of complex mirror neuron systems and that individuals who do not possess a fully functioning version of this mirror neuron system are communicatively hampered. Indeed Fogassi and Ferrari (2007) note that mirror neurons in monkeys are activated when they execute or observe an action[8], but add that these neurons are also activated when monkeys are listening to “action sounds” and that primate cognitive processes may well have formed the basic components of language. Fogassi and Ferrari (2007) offer a striking anatomical contrast to support this theory.

Figure 5: Macaque versus Human Cerebral Cortex, Highlighting Motor Areas of Language

[8]However, remember that in order for monkeys to execute an observed action, it must be contextually appropriate from their vantage point: monkeys will mimic humans and monkeys grasping objects but will not do the same when they see a robot grasping an object or when a human is using pliers instead of hands. (Miall 2003)



As can be seen from above, the monkey brain (A) and the human brain (B) are strikingly different in size and complexity: however, the monkey brain is also missing Broca's Area (BA 44), and its accompanying folds in the brain. Still, a rough location-based approximation between the two is evident and it shows why (Taglialatela, Russell, Schaeffer and Hopkins 2008) can find that when chimps communicate, that part of their brain becomes activated.

Fogassi and Ferrari (2007) take this theory a step further, complementing our hypothesis by noting that communicative neurons are only activated in monkeys by friendly gestures rather than threatening ones. This is not unique to monkeys but it also might be present in several developmentally disabled populations: for instance, Jawaid, Schmolck and Schulz (2008) present that hyper social Williams Syndrome patients may be unable to recognize facial expressions that indicate an external threat. Although no studies exist on this point, it may be useful- and it may help our hypothesis further- to look at whether specific developmentally disabled populations such as Williams Syndrome patients lack the ability to respond to hostility, real or perceived, because they lack the necessary communicative neural structure.

7. Conclusions

This paper began with a hypothesis and a subtheme, namely that we can find a clear evolutionary line from chimps having developed communicative gestures to the human development of speech and that while doing so we can show that the primary distinction between chimps and humans that prevents the latter from developing speech is their smaller brain size coupled with a shorter lifespan and correspondingly shorter time frame for maturation.

While genetics has hampered our subtheme, the overall hypothesis has received considerable ballast: we have shown that chimpanzees are capable of meaningful, communicative gestures: that gesturing precedes speech in humans: and that in fact mirror neurons, which, in humans, organize into complex systems that permit speech have a basic fore-runner in monkeys and that primate cognitive processes may well have led to the basic components of language. This is further supported by having outlined the process of a human learning to communicate which starts with recognition of other's communicating, moves to gestures and is finally vocalized with progressively more finesse as humans grow older.

Questions remain however about how chimpanzee neural structures are organized and how these neural structures have developed over time. Studies may be organized around chimpanzees of different age groups to see if they develop a semblance of these structures as they age and whether chimpanzees that are in laboratories where they are consistently exposed to human speech develop more of such networks as they age compared to chimpanzees who are introduced to these surroundings later in life. In any case, this paper has hopefully contributed to the conversation about this subject.

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