

From manual gesture to speech



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Gestural theory of language origins: Pedigree

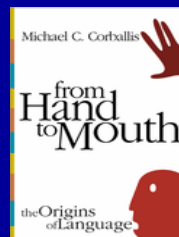
Cresollius (1620), Mandeville (1728), Condillac (1746), Tylor (1868, 1871), Morgan (1877), Wallace (1881), Romanes (1888), Wundt (1912), Paget (1944), Johansson (1949, 1950), Hewes (1973), Wescott (1974), Steklis & Harnad (1976), Engelfield (1977), Kimura (1979), Armstrong, Stokoe, & Wilcox (1991), Kendon (1991), Corballis (1991, 1999, 2002), Donald (1991), Allott (1994), Givon (1995), Rizzolatti & Arbib (1998), Skoyles (1998), Armstrong (1999), Goldin-Meadow & McNeill (1999), Wells (1999), Place (2000), Arbib (2005), Armstrong & Wilcox (2007).

—and more

Two books



Oxford University Press, 2007



Princeton University Press, 2002

The Problem

“... the gestural theory has one nearly fatal flaw. Its sticking point has always been the switch that would have been needed to move from a visual language to an audible one”

—Robbins Burling, *The Talking Ape* (2005, p. 123)

How to answer this?

Burling, R. (2005). *The talking ape*. Cambridge Univ. Press

I will argue that

- The switch was not sudden, but gradual
- Language is fundamentally gestural, with vocal gestures gradually replacing manual ones
- Speech itself is gestural
- Even today, speech is accompanied by manual gestures

Evidence from signed languages

- Signed languages have all the expressive power of spoken languages
- Gallaudet University—instruction entirely in ASL
- Grammatical classes (nouns, verbs, adjectives, etc) as in speech
- Also phrases, sentences, tenses, moods, etc

"Though highly specialized, the language faculty is not tied to specific sensory modalities, contrary to what was assumed not long ago. Thus, the sign language of the deaf is structurally very much like spoken language, and the course of acquisition is very similar."

—Chomsky (2000, p. 121)

Chomsky, N. (2000). *New horizons in the study of language and mind*. Cambridge Univ. Press

But signing and speaking have an important difference

- Signed languages are much more obviously iconic
- Italian Sign Language (LIS): 50% of handshapes and 67% of body locations of signs have iconic motivation
- Same probably true of all signed languages
- This contradicts Saussure's doctrine of "the arbitrariness of the sign" as the hallmark of language

Language re-defined

- Language is embodied communication, ritualized and conventionalized
- It is made up of bodily gestures
- Even speech is a gestural system, not an acoustic one (Motor Theory of Speech Perception)
- In the course of conventionalization, gestures may lose their iconic character

Signs can be iconic but are conventionalised, so the sign for same object (e.g., tree) can vary a lot between languages



Bellugi, U., & Klima, E.S. (1976) *Annals of NYAS*, 280, 514-538

FIGURE 4. Sign for TREE in three different sign languages.

The arbitrariness of speech

- Arbitrariness not a fundamental property of language
- When language is spoken, arbitrariness is simply a consequence of the linear nature of human sound production
- Hockett (1978, pp 274-5): "... when a representation of some four-dimensional hunk of life has to be compressed into the single dimension of speech, most iconicity is necessarily squeezed out"

Hockett, C. (1978). In search of Jove's brow. *American Speech*, 53, 243-315

How language evolved

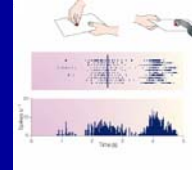
- Given our primate heritage, humans are visuo-manual creatures
- With bipedal stance, the hands and arms provide a natural means of conveying information about the 4D material world
- **In the course of evolution and conventionalization of gestural communication, manual gesture was gradually replaced by vocal gesture**

Further support from

1. The mirror system
2. Cerebral asymmetry
3. Teaching language to apes

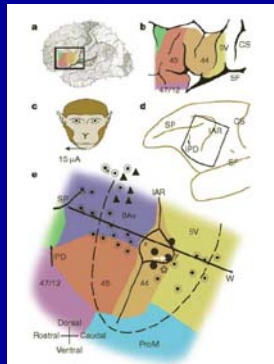
1. The mirror system

- “Mirror neurons” first discovered in Area F5 in the monkey
- These fire when the animal makes a grasping movement, and also when it observes the same movement made by another
- Maps observation onto execution
- Area F5 corresponds to Broca’s area (areas 44 and 45)



Stimulation in Broca homolog also elicits orofacial movements in monkey

- Within area 44, stimulation induces jaw movements
- Hand movements also recorded in one monkey



Petrides, M. et al. (2005). *Nature*, 435, 1235-1238

The mirror system ...

- Includes areas in STS and parietal lobes, overlapping the language areas in humans
- Maps perception onto manual action
- Includes the sounds of action, as well as visual display of action
- Except in humans, no evidence that vocalization is part of the mirror system
- **Language evolved within the mirror system, but was initially manual rather than vocal**

Rizzolatti, G., et al. (2001). *Nature Reviews*, 2, 661-670.

2. Cerebral asymmetry

- Most people are right-handed, suggesting dominant left-hemisphere manual control
- Evidence from apraxia suggests left-hemisphere dominant for purposeful action, even if bimanual
- Left hemisphere also dominant for speech and for signed language
- **Cerebral asymmetry marks the commonality between manual gesture and speech**

3. Language and gesture in apes

- No success in teaching them to speak (*Viki*)
- Some success in teaching a form of sign language (*Washoe*) or use of visual symbols (*Kanzi*, and others)



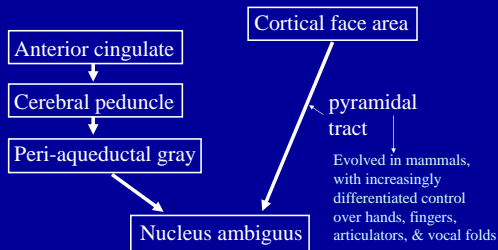
Savage-Rumbaugh, S. et al. (1998). *Apes, language, and the human mind*. OUP.

Kanzi and friend

TWO SYSTEMS OF VOCAL CONTROL

LIMBIC SYSTEM (old)

NEOCORTICAL SYSTEM (new)



Ploog, D. (2002). In T. J. Crow (Ed.) *The speciation of modern Homo Sapiens* (pp. 121-135). OUP

Lack of voluntary vocal control in chimps

Jane Goodall: Chimp unable to suppress pant-hoot on discovery of cache of bananas

"The production of sound in the *absence* of the appropriate emotional state seems to be an almost impossible task for a chimpanzee."

—*The Chimpanzees of Gombe* (1986, p. 125)

Gesturing apes

- Extensive gesturing observed in the wild by Menzel, Goodall, Kortlandt, Plooj, Tomasello. Arm and hand gestures, facial expressions, body postures, grooming
- *Dyadic*, directed toward individuals (unlike vocal calls)
- *Intentional*, unlike vocal calls

Some chimp gestures

Arm-on	Arm-raise	Back-off
Ball-offer	Belly-offer	Direct-hand
Foot-stomp	Genital-offer	Ground-slap
Hand-beg	Hand-clap	Head-bob
Head-shake	Lead	Leg-offer
Lip-lock	Look-back	Point
Poke-at	Push-object	Raise-object
Reach	Rub-chin	Shake-object
Spit-at	Swagger	Throw-stuff
Touch-side	Wave-object	Wrist-offer

—from Tomasello, M. et al., *Evolution of Communication*, 1, 223-259

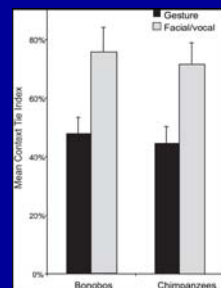
Pointing in Chimps

- Not observed in wild chimps
- Easily taught to captive chimps
- Rapidly spreads through captive population
- About 67% right-handed
- Triadic, involving sender, recipient, and object
- Intentional, involving alternating eye-gaze between object and recipient

—Leavens, D.A. & Hopkins, W.D. (1998) *Developmental Psychology*, 34, 813-822

Flexibility of manual and vocal gestures in great apes

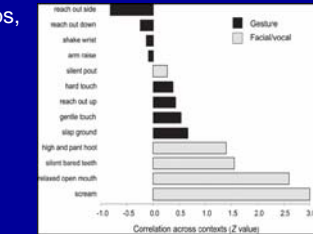
- Manual gestures much less tied to "typical" contexts than facial/vocal gestures in chimps and bonobos



Pollick, A. S. & de Waal, F.B.M., *PNAS*, in press

Flexibility of manual and vocal gestures in great apes

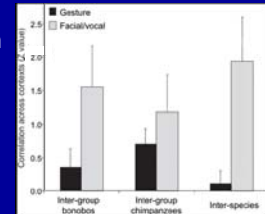
- In bonobos and chimps, lower correlations across contexts for manual than for facial/vocal gestures



Pollick, A. S. & de Waal, F.B.M., *PNAS*, in press

Flexibility of manual and vocal gestures in great apes

- Much lower correlations between groups for manual than for facial/vocal gesture



Pollick, A. S. & de Waal, F.B.M., *PNAS*, in press

Summary of ape research

- Nearest equivalents to language in great apes are gestural, not vocal
- Therefore, language is more likely to have emerged in hominins from manual gesture

Bipedal hominins

Freeing the hands

- Bipedalism freed the hands from locomotion, enhancing gestural communication?
- Classically associated uniquely with the hominin line from 6-7 million yrs BP
- New theory that knuckle-walking chimps and gorillas are the exception, and bipedal stance may go back tens of millions of years*

*Thorpe, S.K.S. *et al.* (2007). *Science*, 316, 1328-1331

“And suited, finally, to vocalization is the upright posture of man, denied to animals; man is therefore summoned, as it were, to his feet. For speech does not aim at hollow extensions in the ground, but demands to pour freely from the lips towards the person addressed, *to be accompanied by facial expression and demeanor and by gestures of the hand*, and thereby to surround itself at once with everything that proclaims man human.”

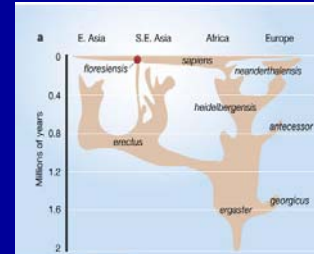
—Wilhelm von Humboldt (1836)

Bipedalism surely enhanced the use of the hands for volitional communication

Homo and the Pleistocene: The rise of true language

The genus *Homo*

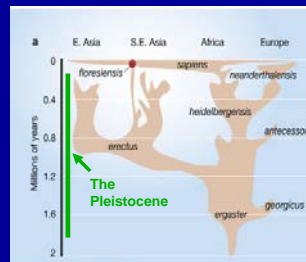
- Rapid and dramatic increase in brain size
- Migrations out of Africa
- Emergence of stone tool industries
- Prolongation of post-natal development



Grammatical language probably evolved during this era

The genus *Homo*

- Rapid and dramatic increase in brain size
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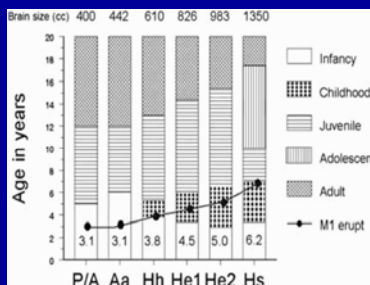
Grammatical language probably evolved during this era

What drove increase in brain size?

- Survival value of enhanced cooperation and communication during the Pleistocene
- The “cognitive niche”—cause-and-effect reasoning to overcome fixed defences of plants and animals
- Emergence of episodic memory, mental time travel, discovery of time, and language
- These all characterized by *recursion*

Tooby, J., & DeVore, I. (1987). In W. G. Kinzey (Ed.), *The evolution of human behavior: Primate models* (pp. 183-237). SUNY Press.

The uniqueness of human childhood



- Childhood critical to development of language
- Unique to genus *Homo*
- Period in which theory of mind, mental time travel emerge

Locke, J. & Bogin, B., (2006). *BBS*, 29, 259-325

Mental time travel

- Distinction between semantic and episodic memory (Tulving, 1983)
- Episodic memory unique to humans?
- Part of more general ability to imagine both past and future events
- Hence **mental time travel** (Suddendorf & Corballis, in press)

Suddendorf, T. & Corballis, M.C. (in press). *Behav. Brain Sci.*
Tulving, E. (2002). *Ann. Rev. Psychol.*, 53, 1-25.

fMRI study

PAST AND FUTURE EVENT ELABORATION

PAST EVENT > CONTROL FUTURE EVENT > CONTROL

- Participants cued by keywords to imagine past and future events
- Sagittal slices show striking similarity

Addis, D. R. et al. (2007). *Neuropsychologia*, 45, 1363-1377

Time and language

- For animals living in the present, simple communication will suffice
- Once the *time* dimension is added, communication is vastly more complex:
 - Need to represent objects and events that are not physically present (conventionalized representation)
 - Need mechanisms to refer to different points in time, past and future (tense)
- **Thus was true language born**

The transition from manual gesture to speech

Main points

1. Close links between manual and mouth movements in primates
2. Gestural communication dominated first by manual gesture
3. Gradual shift to facial and mouthed gesture
4. Addition of cortically controlled vocalization late in evolution, possibly restricted to *Homo sapiens*

Link between hand and mouth in primates

Neuron discharge during grasping with the mouth.

Neuron discharge during grasping with the ipsilateral hand

Neuron discharge during grasping with the contralateral hand

Recordings from area F5 in the monkey brain

Rizzolatti, G., et al. (1988) *Exp. Brain Res.* 71, 491-507.

Also in humans

Subjects vocalize while bringing apple or cherry to the mouth, or watching them brought to the mouth

BRINGING-TO-THE-MOUTH EXECUTION

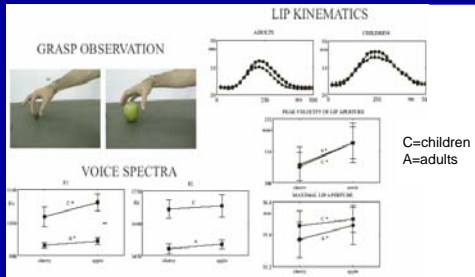
BRINGING-TO-THE-MOUTH OBSERVATION

- A Subject says "ba"
- B Subject vocalizes nonlinguistic sound
- C Observation of action
- D Pantomime of action
- E Nonbiological arm

■ cherry
■ apple

Gentilucci, M., et al. (2004). *Europ. J. Neurosci.*, 19, 190-202.

Subjects say "ba" while watching a person grasping cherry or apple



Gentilucci, M., et al. (2004). *Neuropsychologia* 42, 1554-1567.

Why the connection?

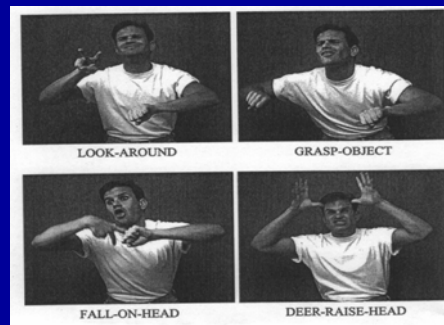
- Probably derives from eating!
- Double hand-mouth command system is present in monkeys, but does not involve vocalization
- (Peter MacNeilage: Speech originated from repetitive ingestive movements of the mouth)

MacNeilage, P.F., 1998. *Behav. Brain. Sci.* 21, 499-546.

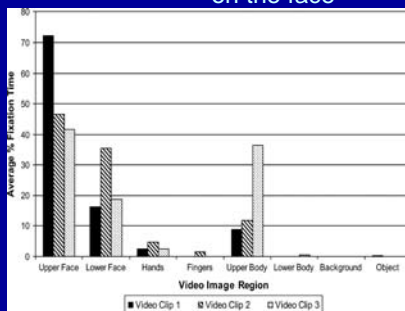
More clues from sign language

- Mostly carried out with the hands
- Also overlaps with the mirror system
- But involves the face as well as the hands
- Hence a link between speech and signing—both involve gestures of the face and hands

The face in action



Deaf people watching signing fixate mostly on the face



A study with British Sign Language (BSL)

Muir, L. J. et al. (2005) *J. Deaf Stud. Deaf Educ.* 10, 390-401

Speech is gesture

- Motor theory of speech perception, and articulatory phonology
- Speech conceived as *gestures* of the lips, the velum, the larynx, and the blade, body, and root of the tongue
- Perception of speech involves recovery of gestures, not acoustic analysis
- These gestures are partly visible (lipreading, McGurk effect, ...)

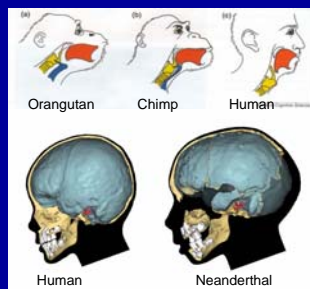
The transition

- Gestural language moved increasingly to the face, as hands became more occupied with manufacture, tool use, and carrying
- The "face" includes the tongue and, eventually, the larynx
- Sound was added to make hidden mouth gestures accessible
- Vocalization also adds the voiced/unvoiced distinction
- **Speech is facial gesture half swallowed**

When was the transition complete?

Changes for speech occurred late in evolution of *Homo*

- Lowering of larynx
- Lengthening of tongue and neck
- Flattening of face
- **These changes not complete even in Neanderthal, 30,000 years ago?**



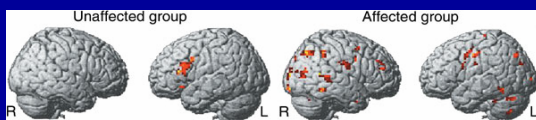
—Lieberman, P. (2007) The evolution of human speech. *Current Anthropology*, 48, 39-46

The FOXP2 gene

- KE family: deficits in speech due to mutation on the FOXP2 gene on chromosome 7
- The primary deficit is oro-facial movement*
- Affected members of the KE family don't show activation of Broca's area when generating verbs
- **FOXP2 gene responsible for introducing articulate vocalization to the mirror system?**

*Watkins, K.E., et al. (2002). *Brain*, 125, 452-464.

FOXP2 and the Mirror System



- Unaffected KE members show activation of Broca's area when generating verbs
- Affected members show bilateral activation *excluding* Broca's area
- Could FOXP2 have assimilated orofacial/vocal control into Broca's area, and the mirror system?

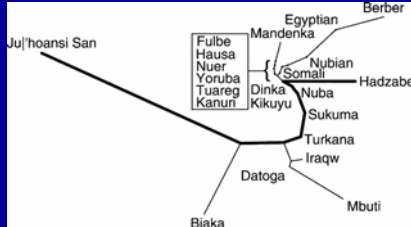
Liégeois, F. et al., *Nature Neuroscience*, 2002, 11, 1230-1237

Evolution of the FOXP2 gene

- FOXP2 underwent 2 mutations in hominids after the split from the apes
- The more recent occurred *not earlier* than "the time since the onset of human population growth, some 10,000 to 100,000 years ago. ... This is compatible with a model in which the expansion of modern humans was driven by the appearance of a more-proficient spoken language"*

*Enard, W. et al. (2002) *Nature*, 418, 871

African click languages



- Time depth of around 100,000 years, to the root of present-day mtDNA variation
- Could clicks be a precursor to vocalization?

Knight, A. (2003). *Current Biology*, 13, 464-473.

Interim summary

- Mechanical, neural, and genetic adaptations for autonomous speech not complete until emergence of *Homo sapiens*, and possibly even more recently
- "... fully human speech anatomy first appears in the fossil record in the Upper Paleolithic (about 50,000 years ago) and is absent in both Neanderthals and earlier humans" (Lieberman, 2007, p. 39)

—Lieberman, P. (2007) The evolution of human speech. *Current Anthropology*, 48, 39-46

Why the switch?

Gesture needs light

- Does not work in the dark, or when obstacles intervene.
- "[African languages are not elaborate enough] to enable a native to state his exact thought. Some of them are very dependent upon gesture. When I was with the Fans they frequently said "We will go to the fire so that we can see what they say", when any question had to be decided after dark, and the inhabitants of Fernando Po, the Bubis, are quite unable to converse with each other unless they have sufficient light to see the accompanying gestures of the conversation."

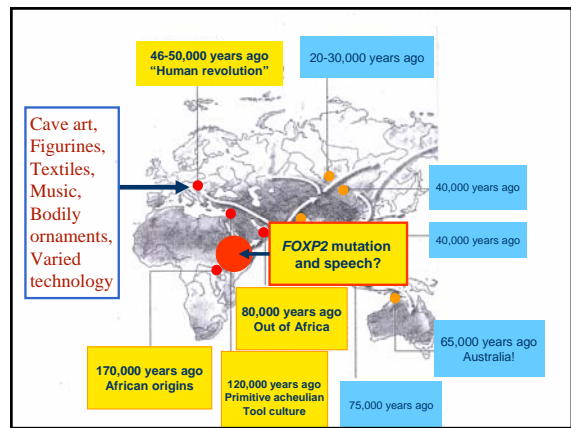
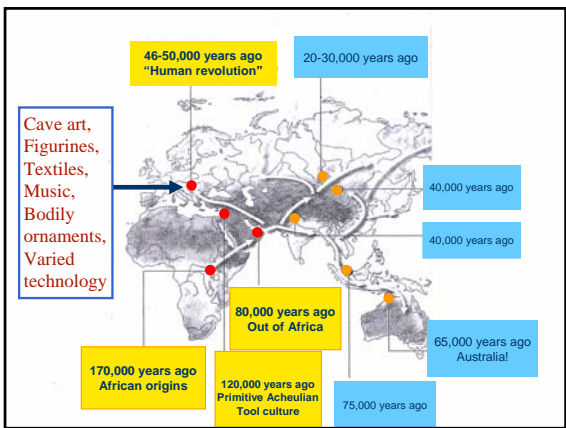
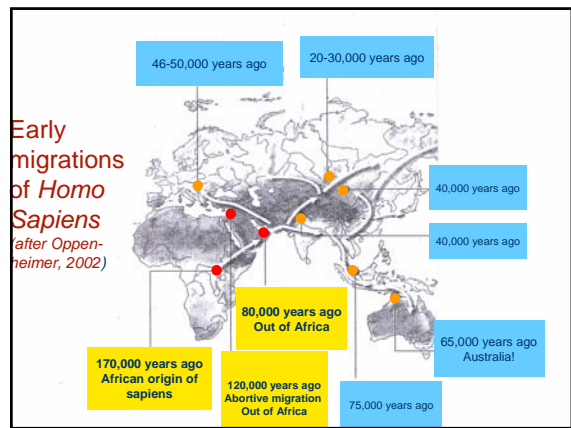
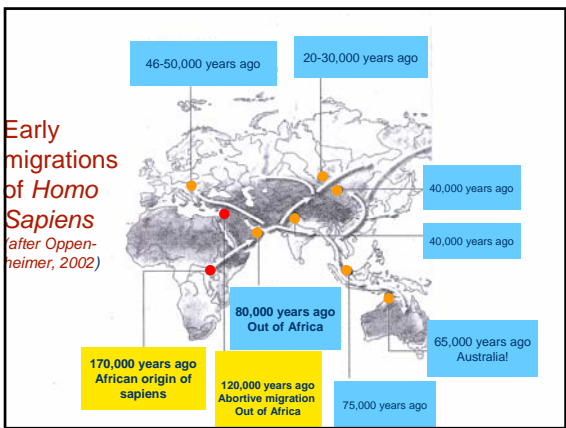
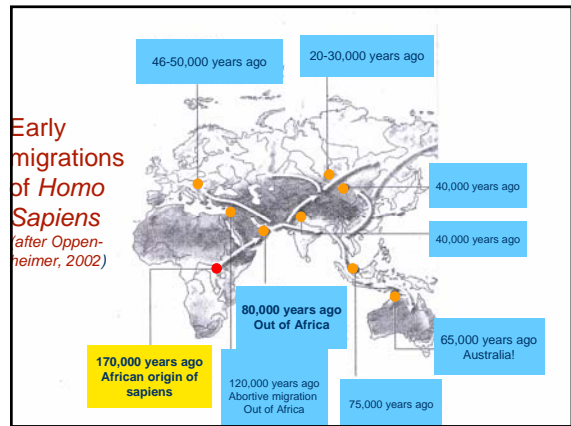
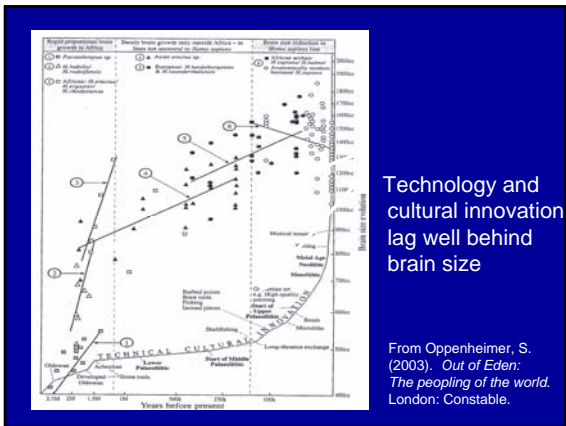
—Mary Kingsley, *Travels in West Africa*, 1897, reprinted 1965, p.504

Speech is energy-efficient

- Gesture is relatively costly in terms of effort
- Speech piggybacks on breathing, and the extra energy required is negligible
- *Words are cheap*

Speech frees the hands

- Allows development of manufacture
- Also allows the development of pedagogy, so that manual activities (e.g., making and using tools, cooking lessons, etc) can be demonstrated and verbally described at the same time.
- Manufacture and material culture did not really take off until the arrival of *H. sapiens*, and lagged well behind the increase in brain size



When *did* *H. sapiens* come out of Africa

- Ingman et al. (2000): 52,000 years ago*
- Oppenheimer (2002): 83,000 years ago
- Petraglia et al. (2007): Evidence of *H. sapiens* in India before and after the Mt Toba eruption of 74,000 years ago**

*Ingman, M., et al. (2000). *Nature*, 408, 708-713.

**Petraglia, M. et al. (2007). *Science*, 317, 114-116

The power of speech

- Responsible for the “evolutionary explosion” and development of modernity?
- Also responsible for the dominance of humans over other hominins, and eventual extinction of them all?
- Are other “revolutions” also dependent on changes in communications systems (writing, internet, cellphones)?

Summary

- Language is based on gestures, and their recognition
- This depends on the mirror system
- In the course of evolution, it evolved syntactic structure, probably during the Pleistocene
- It also shifted from being primarily manual to being primarily vocal
- ... and made us human

And we still gesture as we speak



'And do you, Stephanie, promise to love, honor, and "obey"?'

Thanks to

- Michael Arbib
- Karen Emmorey
- Tecumseh Fitch
- Maurizio Gentilucci
- Tom Givon
- Russell Gray
- Nick Humphrey
- Suresh Muthukumaraswamy
- the late Bill Stokoe
- Giacomo Rizzolatti
- Michael Studdert-Kennedy

—some of whom don't agree with me