Mirror Systems and More
Merged Slides for 2 talks
Hong Kong 08-13

1. Language Evolution: Current Controversies and the Challenges of Multi-Disciplinary Research. Pondering the critiques in Language and Cognition, 2013 5(2/3)

2. It takes mirror neurons and more to build a brain for language

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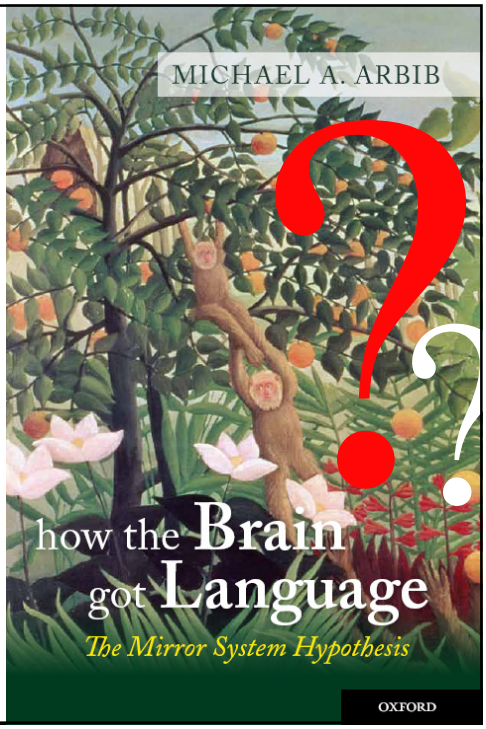
This work was supported in part by the National Science Foundation under Grant No. 0924674



A Motivating Passion

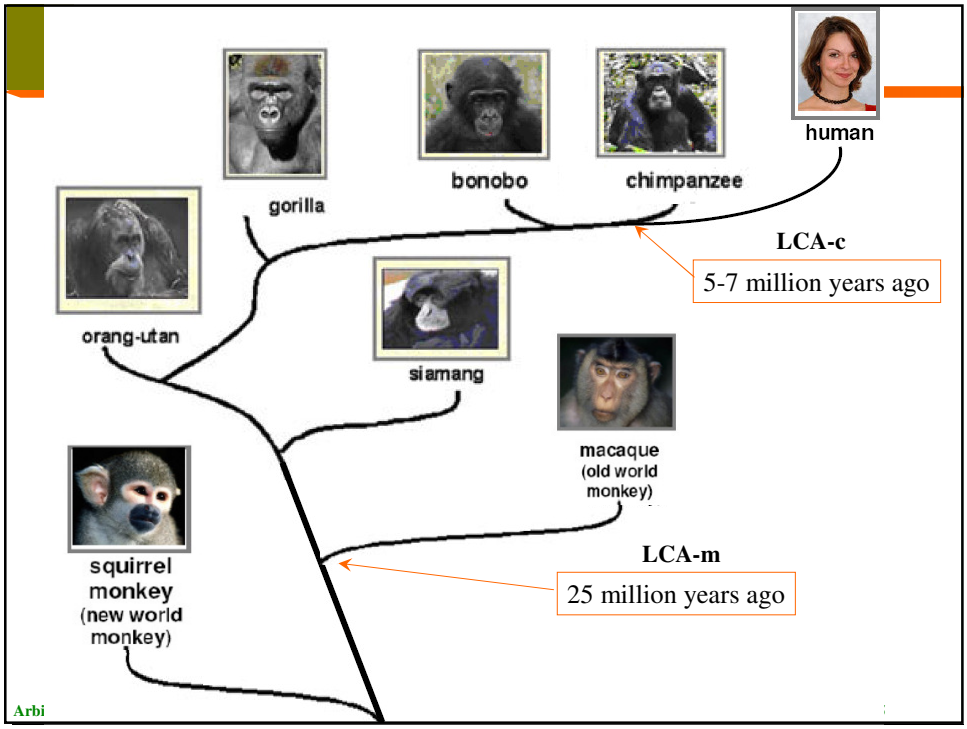
To understand "How the Brain Works"

Linking data on behavior
– action, perception, language and
the memory structures that serve them –
to the **cooperative computation**
(competition and cooperation of diverse patterns of activity)
of "schemas" or neural networks that underlie them

Cooperative Computation in Action

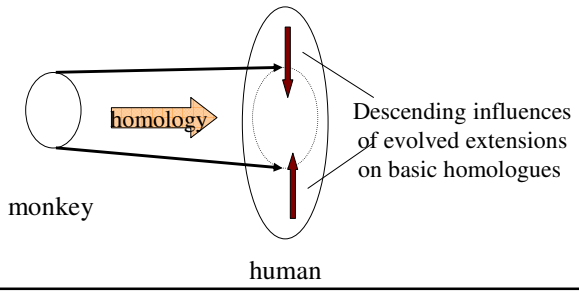
There was a young bard from Japan
Wrote poems that no one could scan
When told it was so
He replied, "Yes I know
But I always try to get as many words into the last line as I possibly can."

What Were the Ancestral Communication Systems?

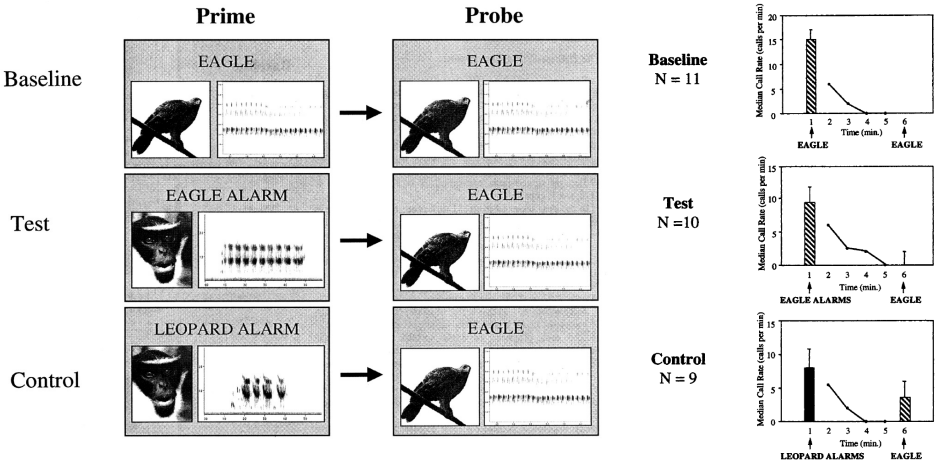


Neuroinformatics and Neural Modeling Strategy

- A database of data on macaque and ape brain regions which are possible homologues of human brain areas relevant to language, and add data on the connectivity of these areas in each species.
- Develop further models, rooted in detailed **macaque** neurophysiology and neuroanatomy, of the mirror neuron system and other brain regions involved in sequential behavior in macaque
- Extend these to models of ape or human circuitry to see what needs to change to support observed behaviors



Monkey Alarm Calls



Habituation transfers semantically not acoustically

K. Zuberbühler, D.L. Cheney and R.M. Seyfarth, 1999, *J. Comp. Psych.* 113: 13-42.

The Ancestral (LCA-m) Communication System

The Leopard Alarm Call for Vervet Monkeys (Seyfarth & Cheney):

- There is a leopard nearby. Danger! Danger! Run up a tree to escape.

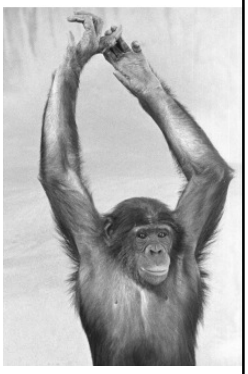
Assumption on the ***Ancestral (LCA-m) Communication System***:

Primate Call System
a limited set of species-specific calls

Oro-Facial Gesture System
a limited set of gestures expressive of emotion and related social indicators

Apes Gesture as well as Vocalize

A juvenile chimpanzee tries to reclaim food that a dominant has taken away by combining the *reach out up* begging gesture with a *scream* vocalization.



An adolescent bonobo male making sexual advances to a female adds the *arm raise* gesture.

Photographs by Frans de Waal.

Vocalizations in nonhuman primates appear to be innate to the species but some
Gestures in apes appear to be specific to one group rather than another (though there is debate concerning the latter claim)

The Ancestral (LCA-c) Communication System

Innate

Primate Call System
a limited set of species-specific calls

Oro-Facial Gesture System
a limited set of gestures expressive of emotion and related social indicators

Innate + Innovative

A gestural opening for language evolution?

But in apes, combinatorial properties for openness of communication are still absent

Language is Multi-Modal

McNeill and Goldin-Meadow on **co-speech gestures**: manual (and facial) gestures naturally accompany speech

The production of co-speech gestures by **blind persons** talking to each other also highlights the ancestral link between hand and language

Co-speech gestures are to be distinguished from the signs which form the elements of the **signed languages employed by deaf communities**

- So: **the brain mechanisms that support language do not especially privilege auditory input and vocal output.**

Our Question: How did a capacity for multimodal language evolve?

A Bridge from Action to Syntax
ASL: American Sign Language

Classifier constructions:

The use of signing space to represent observed/imagined space

HOUSE whole-entity CL + *loc* BIKE whole-entity CL + *loc*

HOUSE located here BIKE Located here

The bike is near the house

Adapted from slide supplied by Karen Emmorey

The Brain's Capability for Language

Language-readiness: the capacity to acquire and use language

- Claim: Being "language-ready" does not imply "having language

Biological Evolution: *The processes of* ***genetic selection*** *that yielded a language-ready brain*

- **The Mirror System Hypothesis:** An account of how and why the human brain differs from that of other primates to make humans "language-ready".

Cultural Evolution: *The processes of* ***non-biological, social selection*** *whereby a variety of languages arose and "cross-pollinated".*

- *Niche Construction* in a feedback loop with (but not necessitating) biological evolution

Properties Supporting Protolanguage Communication

Protolanguage: A system of communication intermediate between ape-like vocal and gestural communication and human language

- **Complex Imitation**
- **Symbolization:** At first, symbols may not have been words in the modern sense
- **Intentionality**
- **Parity: (The Mirror Property)**

Plus 4 more general properties

Criteria for Language

Early Protolanguages → A Spectrum of Increasing Complexity → Early Language → 微博

Parity, Hierarchical Structuring, and Temporal Ordering ***plus***:

Symbolization: The **symbols become words** in the modern sense, with membership in categories tied to:

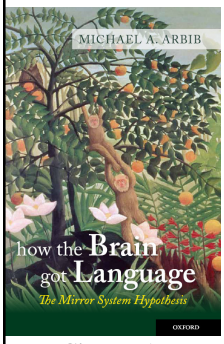
Syntax and Semantics: Syntactic and semantic structures co-evolve to support an increasingly ***compositional semantics***

- I see **recursivity** as an automatic corollary of the expression of meaning concerning hierarchical structures

Beyond the Here-and-Now: Verb tenses or other circumlocutions express the ability to recall past events or imagine future ones.

Learnability: To qualify as a human language, it must contain a *significant subset* of symbolic structures learnable by most human children

Underneath the Lamp Posts



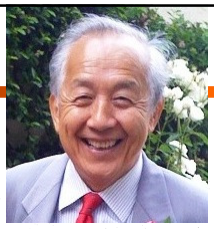
Chapter 1

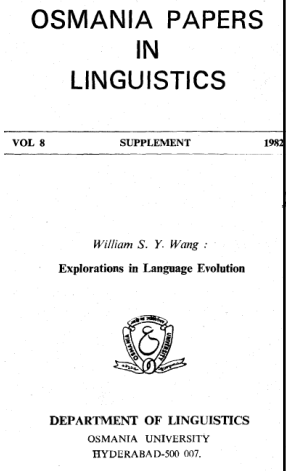
1) Schema Theory for Basic Neuroethology
2) Schema Theory for Vision and Dexterity
3) Neurolinguistics linked to action and perception
4) Social Schemas

Bill Wang Beat Me To it!

"The story is told that a man was seen crawling on his hands and knees around a lighted lamp-post, looking for a key he had lost. …

"The key to the evolution of language also lies far away from us – lost in the dim and remote past of man's earliest developments. … However, it is a key well worth the search, because there is no more critical achievement of the human mind than the invention of language. "





Not one key, but many pieces of a jigsaw puzzle and so we need many lampposts:

- Communication of Primates … and others
- Social Interaction More Generally
- Comparing the Macaque and Human Brain … and modeling them
- Apraxia and Aphasia
- Sign Language
- Psycho/Neuro Linguistics: What happens in the human head?
  - A real concern with **processes** that underlie performance
- Language Acquisition
- Historical Linguistics/Lexeme Formation + Grammaticalization
- Emotion and Motivation
- Evolutionary theory: Selection, niche construction, genetics
- Computational modeling of interacting agents
- Archeology & Anthropology

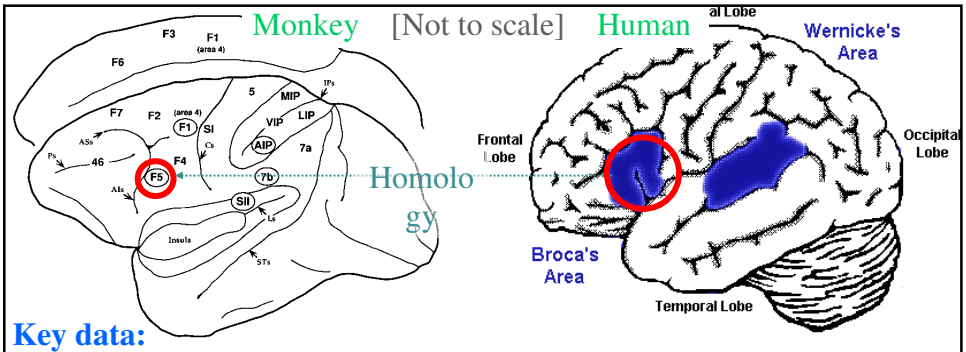
Our Challenge:

- **Not only to design well-focused studies "under the light of each lamp post"**
- **But also to integrate what we learn from the localized illumination of each.**

Introducing the Mirror System Hypothesis

or should it be called

The Complex Imitation Hypothesis of the Language-Ready Brain?

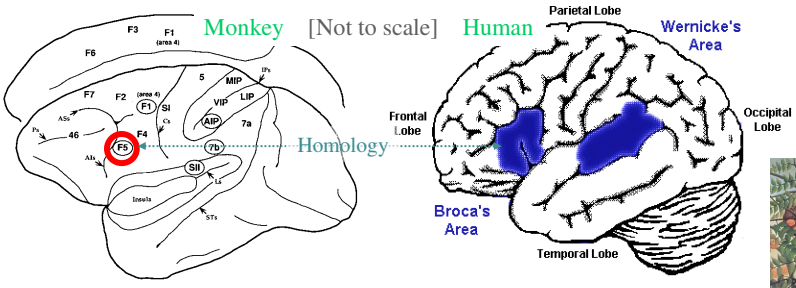


Key data:

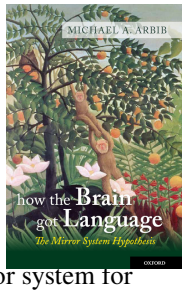
- Monkey F5 (with its mirror system for grasping) is homologous to human Broca's area
- Imaging studies show activation for both grasping and observation of grasping in or near Broca's area

Language is a Multi-Modal System:
Face, Hands, and Voice ….
Co-Speech Gestures
Signed languages of the Deaf

The Mirror System Hypothesis:
From "praxis" to communication



Rizzolatti, G, and Arbib, M.A., 1998, *Language Within Our Grasp*, *Trends in Neuroscience*, 21(5):188-194.



The **evolutionary basis** for **language parity** is provided by the mirror system for grasping, rooting speech in communication based on manual gesture

A neural basis for a gestural origins view of the evolution of language

Extending the Mirror System Hypothesis

Pre-Hominid:
Grasping

A mirror system for grasping: **LCA-m**

A simple imitation system for grasping: LCA-c

↓ ***Hominid Evolution***

A complex imitation system: *complex imitation* combines

- the ability to recognize another's performance as a set of familiar movements the ability to use this recognition to repeat the performance, and
- (more generally) to recognize that another's performance combines variants of known actions, with increasing practice yielding increasing skill

"Naïve" Pantomime: Adapting the action repertoire to **open** up communication

Protosign: a manual-based communication system, breaking through the fixed repertoire of primate vocalizations to yield an **open** repertoire

Protospeech and multi-modal protolanguage: resting on the invasion of the vocal apparatus by collaterals from the protosign system

Cultural Evolution in Homo sapiens

Claim: Once early *Homo sapiens* emerges, cultural change dominated biological change:

From protolanguage to language: Emergence of grammar; Co-evolution of cognitive & linguistic complexity accompanies construction of new "cognitive niches"

Some second-order Baldwinian evolution might fall within this evolutionary loop:

- Increasing control over vocal articulators
- Increasing capacity for symbolic working memory

The Complex Imitation

A Crucial Intermediary

Simple Imitation

Beyond the mirror system for grasping for LCA-m (human and monkey):

Masako Myowa-Yamakoshi:

- The "imitation" employed by chimpanzees focuses on moving objects to objects rather than on the structure of movements per se.

A simple imitation system for grasping
for LCA-c (human and chimpanzee)

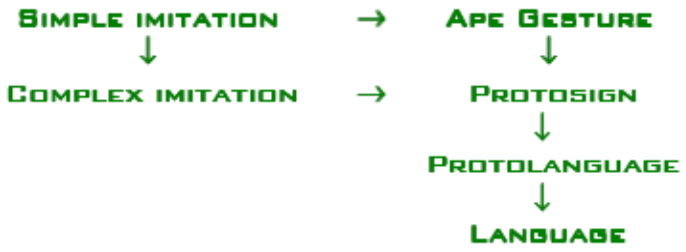
Key Hypothesis: Bringing in Complex Imitation

Hominid Evolution yields a ***complex imitation system:***

- The ability to recognize another's performance as a set of familiar movements
- The ability to use this recognition to repeat the performance, and
- More generally: the ability to recognize that another's performance combines *variants* actions to approximate the performance on this basis, with increasing practice yielding increasing skill.

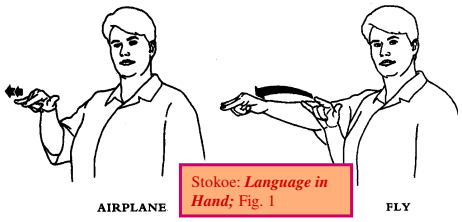
Note utility for language learning and use once this can be applied to words and words streams – ***but it evolved*** (we claim) ***to support praxis***

Imitation: From Praxis to Communication



- The vocal repertoire of nonhuman primates is relatively fixed
- But simple imitation allows apes (and, presumably, the common ancestor of apes and humans) to acquire a small but open repertoire of communicative manual gestures
  - ontogenetic ritualization + social learning

Pantomime is Transitional from *Use of Complex Imitation for Communication* to *Protosign*



Stokoe: ***Language in Hand;*** Fig. 1

- Ambiguity in pantomime may have provided an "incentive" for coming up with an arbitrary gesture to distinguish the two meanings

Note: ASL is a full human language, not a protosign system

Two key parts of the Hypothesis:

Pantomime exploited complex imitation to create an open semantic space for communication:

- The ability to create an open-ended set of complex messages exploiting the primates' open-ended manual dexterity

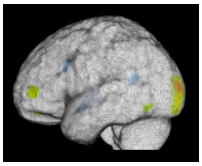
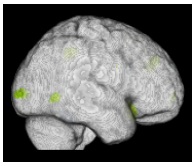
This leads to discovery of the use of abstract gesture:

- As a pantomime becomes familiar to a group, it may become ritualized and thence become a symbol recognized only be members of the group, but not by a general ability to interpret
- Once a group has acquired the understanding that new symbols can provide non-iconic messages, the difficulty of separating certain meanings by pantomime encourages creation of a **protosign system.**

Dissociating pantomime from sign language

Pantomime and signing dissociate with left hemisphere damage.

But there is no difference between "pantomimic" and non-pantomimic ***signs***

BRUSH-HAIR


READ

Slide after Karen Emmorey

The path to proto-speech is indirect

From Vocalization to Manual Gesture and back to Vocalization

Hominid Evolution

- a **complex imitation system** for grasping
- a **manual-based communication system**, breaking through the fixed repertoire of primate vocalizations to yield an open repertoire
- **proto-speech** resting on the "invasion" of the vocal apparatus by collaterals from the communication system based on F5/Broca's area

Of course, many influential scholars hypothesize evolution of speech from vocalization purely in the vocal/auditory domain – with co-speech gesture a "negligible" side effect.

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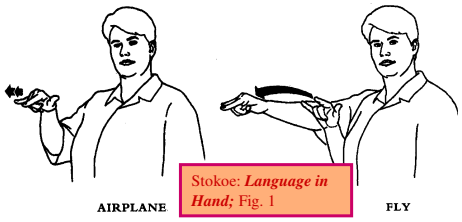

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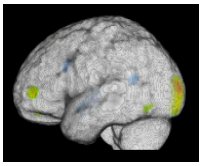

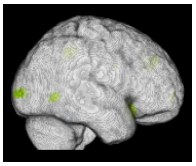

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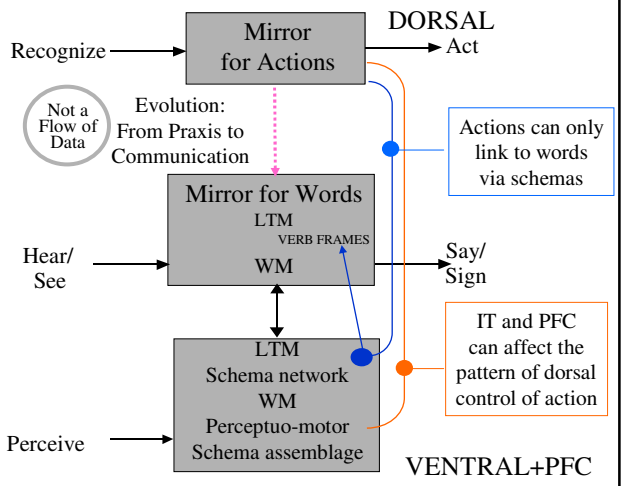
Stressing a Mirror for Words-as-Phonological-Actions

The phonological form gains its meaning by being linked to an assemblage of perceptual and motor schemas which support both perception and the planning of action

The dorsal stream is responsible for setting the parameters of action while the ventral system is responsible for selection among possible actions

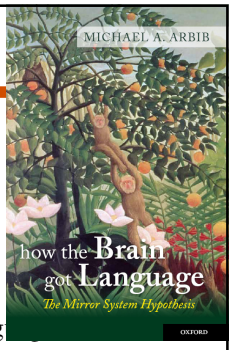


Arbib, MA, 2006, Aphasia, apraxia and the evolution of the language-ready brain, *Aphasiology*, 20:1–30

***How might our ancestors with language-ready brains* but only protolanguage**

DISCOVER
a lexicon and grammar?
(and the general idea thereof)

Cultural Evolution of Homo Sapiens *based on a "language-ready brain":*



In *Homo sapiens*, cumulative brain changes support
- a complex imitation system including complex action recognition
- pantomime supporting an open-ended semantics
- protosign then provides scaffolding for protospeech:

These then develop together in an expanding spiral.

The result: **a language-ready brain** with protolanguage but no lang

- Language then emerges over tens of millennia of *cultural* evolution
  - from protowords linked to action-object frames
  - via fractionation
  - to words and constructions building on verb-argument structures

to yield
- syntax with a compositional semantics and
- co-evolution of cognitive & linguistic complexity

Putting Protowords Together

The Leopard Call (anterior cingulate cortex and brainstem):

- The instinctive call is equivalent to
  There is a leopard nearby. Danger! Danger! Run up a tree to escape

Hypothetical Protowords that "go further" (the lateral brain of, perhaps,* Homo erectus*):

- One protoword is equivalent to
  There is a dead leopard – let's feast upon it.
  is embellished by pointing
- The other protoword is equivalent to
  There is a leopard – let's hunt it so we can feast upon it.
  is embellished by pointing and pantomime of hunting strategies

Items begin to be put together, but the protowords are still holophrases (unitary utterances) – there is, e.g., no word for leopard common to both of them.

From Holophrases to Language

Hypothesis:

a) The protolanguage of *Homo erectus* and early *Homo sapiens* was composed mainly of **holophrases**

- Cf. Alison Wray, 1998: Protolanguage as a holistic system for social interaction.

b) Commonalities between two structures could yield

- the isolation of that commonality as a gesture or vocalization betokening some shared aspect of the event, object or action denoted by each of the two structures
  - Wray 2000: how this might have operated in protohumans
  - Kirby 2000: a related computer model
- This could in time lead to ***the emergence of a construction*** for "putting the pieces back together", with the pieces becoming instances of a widening class of slot fillers

Pantomimic example: Holophrases for "open door" versus "close door" may precede the **invention** of a word for "door."

Complex Imitation Revisited

Recall: Complex imitation combines

- The ability to recognize another's performance as a set of familiar movements
- The ability to use this recognition to repeat the performance, and
- More generally: the ability to recognize that another's performance combines *variants* actions to approximate the performance on this basis, with increasing practice yielding increasing skill.

Mechanisms serving inventing and acquiring a language

Complex imitation makes fractionation possible:

- For protohumans: this could lead to the invention of new (proto)words and constructions.
- For the modern child: this provides the basis for understanding that sound patterns can be dissected into strings of words, and that these words can be grouped by constructions.
- The constructions become of greater or more focused applicability
  - on a historical time-scale as new words and constructions are invented over the course of many generations
  - on a developmental time-scale as the child has more experience of using fragments of the ambient language to understand and be understood.

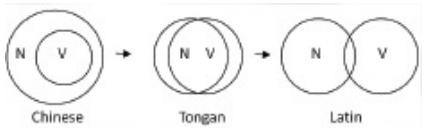
From Holophrases to Language

Many further ways of expressing relationships were *discovered* piecemeal by *Homo sapiens*. Possibilities include

- adjectives, conjunctions such as *but*, *and*, or *or* and *that*, *unless*, or *because,* etc., might well have been "post-biological" in their origin.
- The one word ***sour*** halves the number of fruit names to be learned
- Separating verbs from nouns allows one to learn only *m+n* words to be able to form *m*n*m* of the most basic utterances.

The result: A spiraling co-evolution of communication and representation, extending the repertoire of achievable, recognizable and describable actions

- And recall (CIEL-5) SHEN Jiaxuan on "Nouns and Verbs: Evolution of Grammatical Forms



Acquiring a Language

Jane Hill (1983) showed that the child may first acquire what the adult perceives as two-word utterances as holophrases (e.g., "want-milk") prior to developing a more general construction (e.g., want x") in which "x" can be replaced by the name of any "wantable thing"

Further experience will yield more subtle constructions and the development of word classes like "noun" defined by **their** syntactic roles in a range of constructions rather than their meaning

Classes of slot fillers may be semantic, "semantico-syntactic" or syntactic

Ontogeny does not recapitulate Phylogeny

Adult hunters and gatherers had to communicate about situations outside the range of a modern 2-year old

Protohumans were not communicating with adults who already used a large lexicon and set of constructions to generate complex sentences

Nonetheless, I argue that protolanguage and language emerged through the invention of an increasingly subtle interweaving of (proto)words and (proto)constructions, and that the same basic mechanisms may have served both protohumans inventing language and modern children acquiring the existing language of their community

Phonology Emerging

Duality of Patterning

In speech

- *meaningful* units are composed from a smaller set of *meaningless* units as when discrete sounds combine to form words
- words combine to form phrases which combine to form sentences

Definition: The ***phonology*** of a language comprises a fixed set of meaningless units together with the "rules" whereby they can be constructed into meaningful units

Stokoe (1960) demonstrated that a sign language also has duality of patterning – meaningless handshapes, locations, and movements combine to form a large set of lexical items. This provides the basis for ***sign phonology***

The Emergence of Phonology

Pantomime does not need phonology

- we may vary the pantomime of opening a door in many many ways
- Conventionalization of such a pantomime will capture aspects of one of the many possible performances rather than being built from constituents.

Early utterances of protospeech might

- echo the movements of a protosign; or
- come closer to the vocalization of a cat than the "meow" that invokes the phonology of English.

But as Hockett (1987) says:

- "If a vocal-auditory [or gestural-visual] system comes to have a larger and larger number of distinct meaningful elements, those elements inevitably come to be more and more similar to one another in sound [or appearance, respectively]"
- and this would provide the pressure for segmenting protowords into pieces which could then be replaced by an increasingly conventionalized system of "meaningless units"

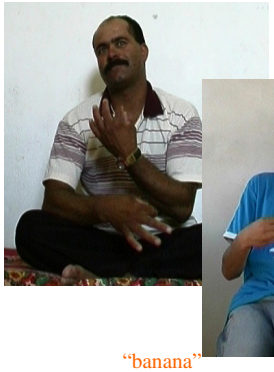
Fractionation: Emergence of Shared Components

We hypothesized that "semantic fractionation" can define new meaningful elements and the constructions that combine them.

We now add that the same mechanisms could yield "motor fractionation" (whether manual or vocal) that defines new meaningless elements as the basis for phonology.

Observation: The components are "emergents" of this process and further the move away from iconicity.

Variation in Al-Sayyid Bedouin Sign Language (ABSL) Signs "close" to pantomime



"banana"

"dog"

Aronoff et al. (2008) find an unexpectedly high degree of inter-signer variation in Al-Sayyid Bedouin Sign Language

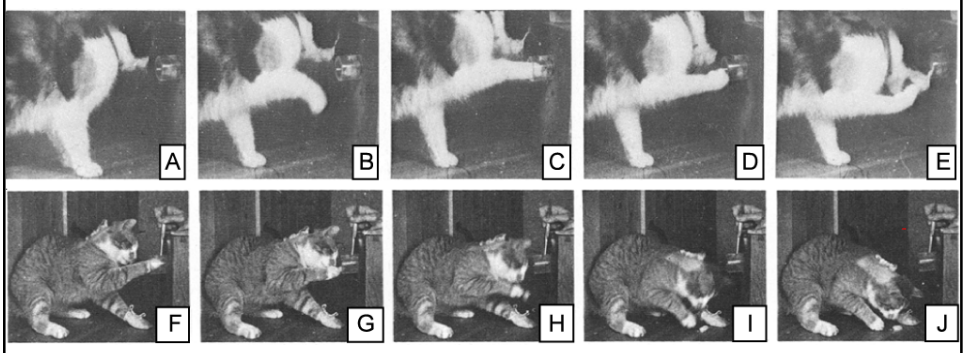
- e.g., "tree" "dog" and "banana" remain close to pantomime though the signs within a family may be similar.

suggesting that linguistic proficiency *can* occur without duality of patterning

- a (sign) language can occur without phonology

Computational Modeling of the Brain: Action, Perception, Communication

Alstermark's Cat – Flexible Action Patterns and their Rapid Reorganization



From Alstermark et al. (1981)

Two Key Ideas

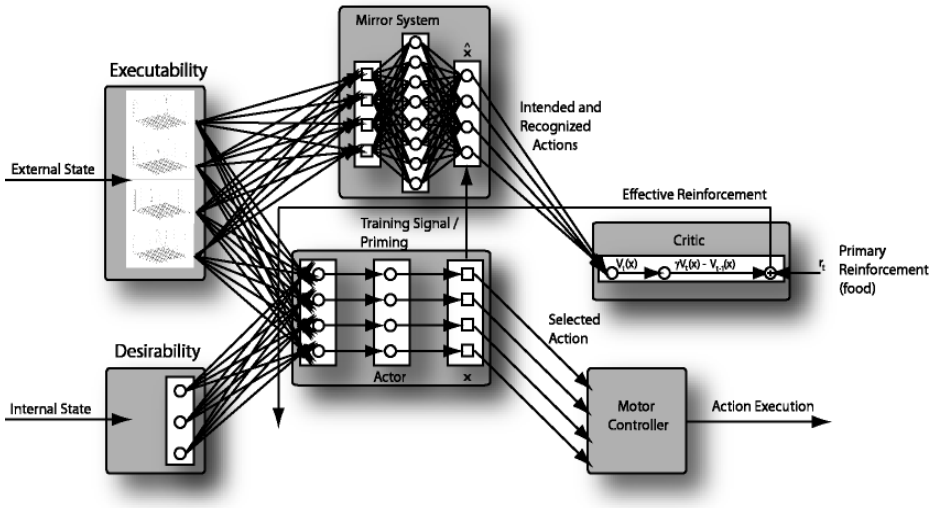
Motor schema activation determined by executability *and* desirability:

- **Desirability** – Based on drives/goals & subgoals/the internal state; dynamically updated via reinforcement learning
- **Executability** – Determined by affordances /the external state and probability of action's success; dynamically updated by end-state of actions

A New Role for Mirror Neurons: What Did I Just Do?

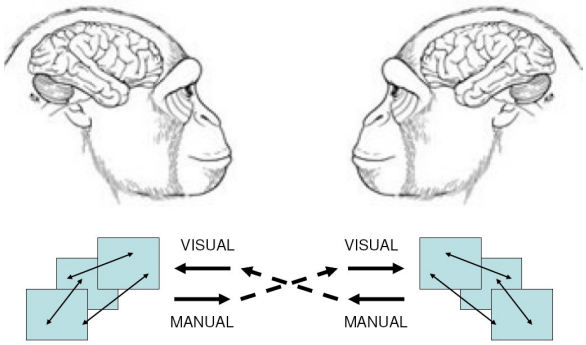
- An observation/execution matching (mirror) system may contribute to rapid reorganization of motor programs in the face of disruption when a known schema can be recognized as "filling the gap" for disrupted schemas

The Augmented Competitive Queuing (ACQ) system



Dyadic Brain Modeling

Interacting agents, yes: But where brain and body of each agent are crucial to the investigation:



Learning from Primate Communication

Klaus Zuberbühler: Acquired mirroring and intentional communication in primates

[This is the first slide referring to titles and authors of commentaries in *Language and Cognition* 2013, 5(2-3)

"primate studies show … that non-linguistic vocalisations are governed by psychological experiences, perhaps similar to what underlies and governs linguistic communication.

"Of course, it is not possible for a chimpanzee to explain to another what it had for breakfast, but it can indicate the location of food, inform others about danger, or choose to remain silent if social conditions are unfavourable."

Ontogenetic Ritualization of Gesture in Apes

Group-specific gestures have been observed in ape populations, suggesting a role for social learning. (Another Controversy)

Tomasello, Call et al proposed ***ontogenetic ritualization*** as a means whereby (some) ape gestures could emerge:

(i) Individual A performs praxic behavior X and individual B consistently reacts by doing Y

(ii) Subsequently, B anticipates A's overall performance of X by starting to perform Y before A completes X.

(iii) Eventually, A anticipates B's anticipation, producing a ritualized form X^R of X to elicit Y

A Hypothetical Example: Beckoning

1) **Child reaches out, grabs, and tugs on Mother**, leading Mother to move towards Child as a response.

2) Child reaches out, grabs, and begins to tug on Mother, but Mother moves sooner towards Child.

3) Child reaches out and makes contact with Mother as if to grab Mother, and Mother quickly moves towards Child.

4) Child reaches out towards Mother— intending to make contact with her— and Mother responds by moving towards Child before contact.

5) Child reaches out towards Mother, and Mother quickly responds by moving towards Child.

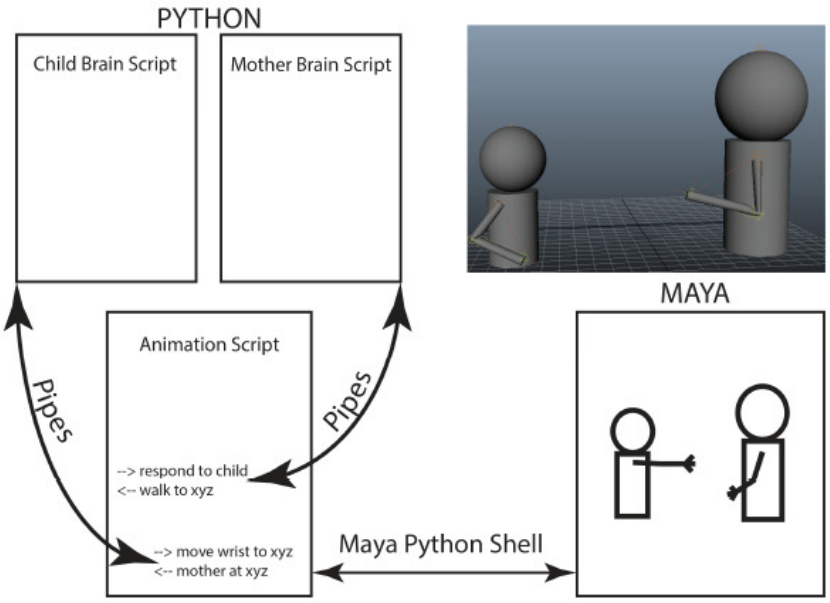
6) **Child beckons Mother** to move towards her.

National University of Singapore

A Model:

Arbib, M. A., Ghanesh, V., & Gasser, B. (2014). Dyadic Brain Modeling, Ontogenetic Ritualization of Gesture in Apes, and the Contributions of Primate Mirror Neuron Systems. *Phil Trans Roy Soc B*

Computational Comparative Neuroprimatology: *Each Brain Script Extends the ACQ Model* in the same way



Comparing the Macaque and Human Brain

Leonardo Fogassi, Gino Coudé, and Pier Francesco Ferrari: The extended features of mirror neurons and the voluntary control of vocalization in the pathway to language



Marco Tettamanti: A research program in neuroimaging for an evolutionary theory of syntax

Francisco Aboitiz: How did vocal behavior 'take over' the gestural communication system?

The Mystery of Motivation

Peter Ford Dominey: The tip of the language iceberg

Issue: Not just how we got to language but also
"What motivated us to communicate in more and more detail?

Tomasello: From Instrumental to Declarative Communication

Learning from Sign Language

Wendy Sandler: Viva la différence: Sign language and spoken language in language evolution

Karen Emmorey: The neurobiology of sign language and the mirror system hypothesis

A Bridge from Action to Syntax
ASL: American Sign Language

The use of **signing space** to represent observed/imagined space


HOUSE


whole-entity CL + *loc*


BIKE


whole-entity CL + *loc*

HOUSE located here BIKE Located here

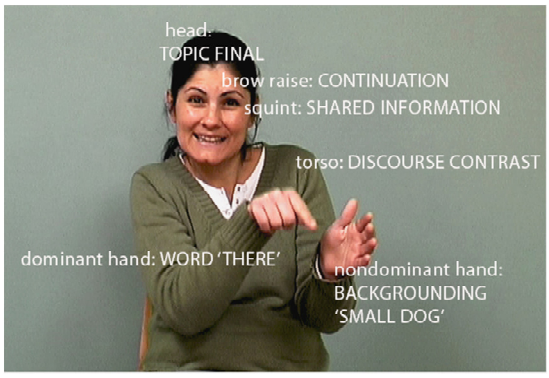
The bike is near the house

Adapted from slide supplied by Karen Emmorey

Sign Language: A Wealth of Effectors

eyeballs: gaze (pointing; questioning; referential shift)

head: topic marking; constituent boundary marking; question marking; prominence; continuation/dependency; referential shift;



upper face (brows, eyelids, cheeks): information status (questions; shared information; focus,etc.); utterance type and constituent boundary marking (with blink); character perspective

lower face (tongue, lips, cheeks): adj., adv. modification; mouthing of spoken words

torso: referential shift; discourse contrast

hand(s): words (phonology; morphology); phrase final prominence; rhythm; boundary strength

nondominant hand: phonological element in words; independent classifier morpheme; discourse backgrounding

[From Wendy Sandler]

Carol Padden says:
"It's hard to appreciate how fast signers can get if you are not already a signer."

Spatial attention & signing space

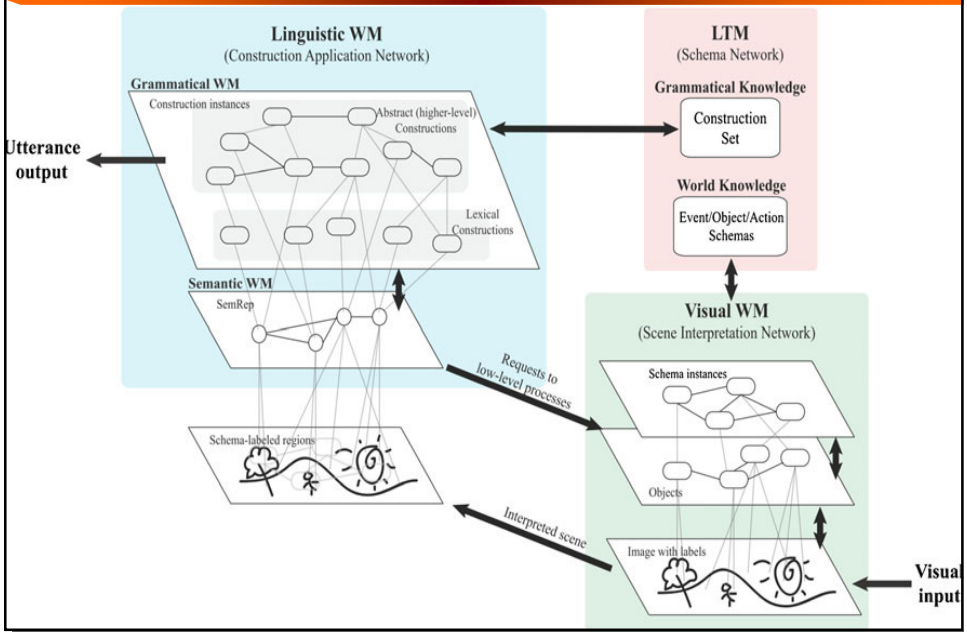
Almor, Smith, Bonilha, Fridriksson, and Rorden (2007):

Using fMRI, they found that reading pairs of sentences (visual coding of speech!) with repeated names elicited more activation than pronouns in the middle and inferior temporal gyri and intraparietal sulcus.

They suggest that the latter activation is related to **spatial attention and perceptual integration.**

We suggest that this may relate to the use of signing space.

A Model of Visual Scene Description: SemRep and Template Construction Grammar



Learning from Linguistics
a) Acquisition of Language
b) Grammaticalization

Holger Diessel: Where does language come from? Some reflections on the role of deictic gestures and demonstratives in the evolution of language

Linking demonstratives as a syntactic category to the physical action of pointing (Again: language is multi-modal)

Pointing is a crucial human gesture for sharing information that is not seen in nonhuman primates in the wild

As **Diessel** observes: ***Demonstratives*** "constitute a unique class of expressions that speakers of all languages use in combination with pointing gestures to establish joint attention, a cognitive … [process essential for] imitation.

They are used not only to direct the interlocutors' attention to concrete entities in the outside world, … but also to organize the information flow in discourse, which in turn leads to their development into grammatical markers.

Language acquisition: The gestural use of demonstratives provides a powerful mechanism for the child to engage in verbal activities with a limited vocabulary. With age, language becomes more independent from gesture and situational cues though demonstratives continue to play an important role even in adult language.

Grammaticalization: Demonstratives in the emergence of grammar – strengthens relevance of grammaticalization to MSH since Diessel argues that demonstratives have to be kept separate from both content words and function words.

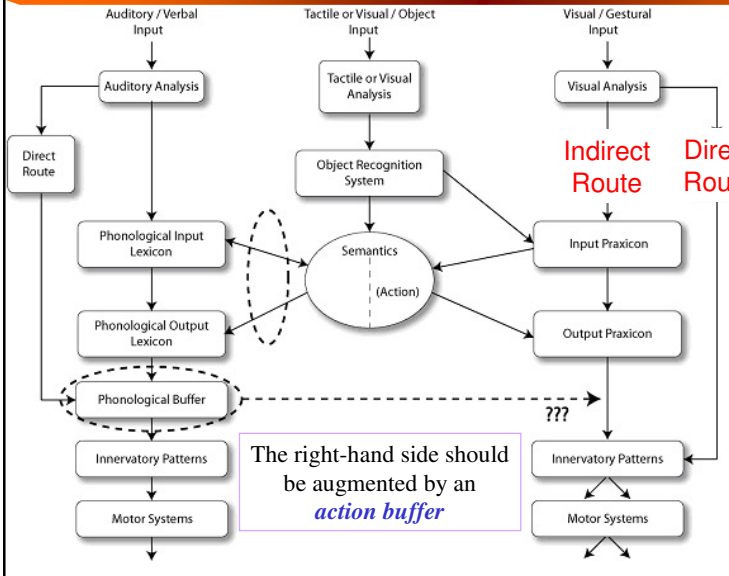
Learning from Apraxia and Aphasia

Mariella Pazzaglia: Action and language grounding in the sensorimotor cortex

Alena Stasenko, Frank E. Garcea, and Bradford Z. Mahon: What happens to the motor theory of perception when the motor system is damaged?



A Conceptual Model for Apraxia
(Rothi, Ochipa, and Heilman, 1991)



An action may be imitated via the

- ***indirect route*** in which mirror neurons (in the *input praxicon*) activate known motor schemas (the *output praxicon*) or
- ***direct route*** in which the action is imitated as an assemblage of meaningless gestures

"The Wrong Way Round"

Rothi et al.:

- Using the Patterson-Shewell model of language (word repetition) to inspire a model of praxis (imitating an action)

Our enterprise:

- To understand language through an evolutionary account grounded in praxis.

But we did **not** *evolve to make meaningless gestures*

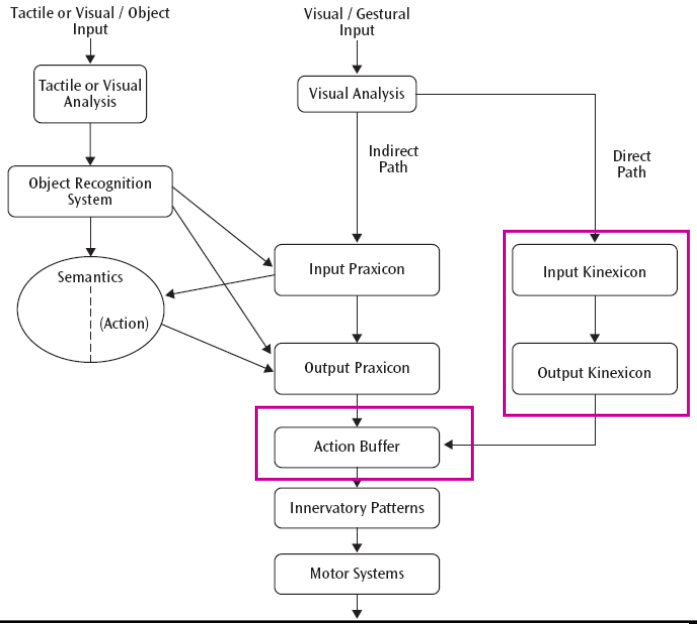
Hypotheses:

- The direct route evolved so that familiar ***tweaks*** (small intransitive movements that are frequent components of many actions) could be used to adjust a known action to better match an observed novel action
  - yielding much faster adaptation than trial-and-error learning in a vastly larger motor search space
- The direct route was later exapted for novel gesture imitation

The direct route is, in evolutionary terms, more sophisticated than the indirect route

- the passage from the common ancestor with monkeys to humans involves the ability to dissociate (some) motions from explicit goals

The Theory of Tweaks



A Key Change of Perspective

Not direct path *or* indirect path

But direct path *and* indirect path

New clinical studies are needed to probe the *integration* of the 2 routes

Hartmann, Goldenberg et al. (2005): "It takes the whole brain to make a cup of coffee."

Subjects were asked to prepare coffee with a drip coffee maker and fix a cassette recorder, tasks which differentially involve retrieval of functional knowledge from semantic memory, inference of function from structure, and solution of multi-step problems.

Aphasic left brain damaged patients:

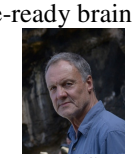
- Difficulties with making coffee were correlated with aphasia and with defective retrieval of functional knowledge from semantic memory.
- Coffee making showed strong correlations to tests of verbal abilities and to non-verbal tests of functional knowledge, suggesting that these associations reflect the difficulties in retrieving script-like instructions for use from semantic memory

Right brain damaged patients:

- Particular difficulty in keeping track of multi-step mechanical problems which were stressed more by the cassette recorder task, despite the flawless performance of these patients when asked to demonstrate the use of single tool-object pairs like key and padlock.
- Fixing the recorder depended less on scripts and more on trial and error [and working memory to keep track of progress] than on retrieval of instructions.

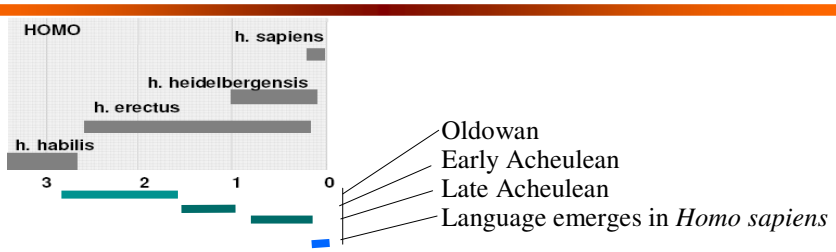
Learning from Archeology & Anthropology

Benoît Dubreuil and Christopher Stuart Henshilwood: Archeology and the language-ready brain

Chris Sinha: Niche construction, too, unifies praxis and symbolization

Linking the Evolution of Tool Use and Language: A Preliminary Hypothesis

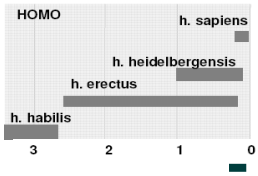


The Oldowan was limited to simple imitation and communication with a limited repertoire of vocal and manual gestures akin to those of great apes

The early Acheulean was *transitional* between simple and complex imitation, with the transfer of skills being limited in depth of hierarchy; these protohumans communicated with a limited repertoire of gestures not much larger than those of a group of great apes

The late Acheulean was the period in which complex imitation was consolidated and communication gained an open-ended semantics through the conscious use of pantomime, with increasingly rich memory structures holding hierarchical plans for both praxis and communication.

From 200 kya to 50 kya (more or less)



Homo sapiens emerged around 200 kya and was the first species of *Homo* with a language-ready brain.

However, it took more than 100,000 years for the developing power of protolanguage to yield the first true languages with their consequent impact on the acceleration of ***cultural evolution***.

Sinha agrees but Dubreil & Hinshelwood want to push language back much further.

Symbolic use of pigments

http://archaeology.about.com/od/middlepaleolithic/ss/Painting-At-Blombos-Cave_2.htm

Image © Science/AAAS

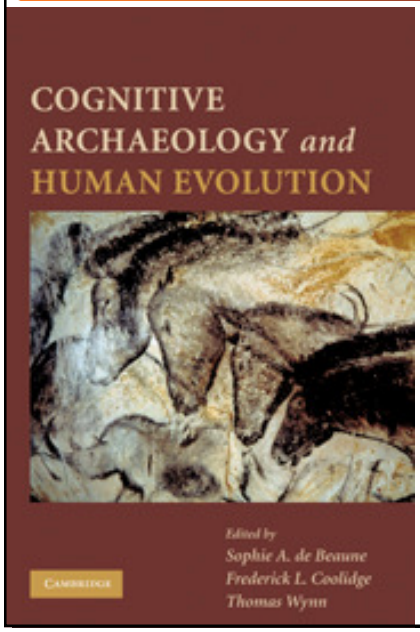
Archeologists at Blombos found the remains of what appears to be two toolkits for creating ochre pigments, located very close together and dated to 100,000 years ago. Ochre is used by people as pigment in all parts of the world.

The abalone shell Tk2-S1 in situ before excavation with an ochre covered grindstone on the shell lip.
Note the red color of the ochre on the shell.
Five fragments of pigment dated between 400 - 260 kya show traces of use.

Dubreil & Hinshelwood: "If pigment use is an archaeological indication of symbolic behavior … *and indirectly of language* [danger!], then the origin of these abilities, traditionally attributed to *Homo sapiens* has to be considered more ancient than commonly accepted." Fascinating data but note that sudden jump to "language."

Counter-claim: Protolanguage would suffice for the relevant social interactions.

Needed: A cognitive archeology in which to locate language



Ongoing issue: What can we learn about language from traces of objects?

a) We try to infer behavior

b) What then of the communication that might have made it (or its transfer) possible?

Editors:

Sophie A. de Beaune, Université Lyon III

Frederick L. Coolidge, University of Colorado, Colorado Springs

Thomas Wynn, University of Colorado, Colorado Springs

A musical origins theory

But What About Music?

The (Extended) Mirror System Hypothesis: a path from praxic use of the hands via communicative gestures, pantomime, protosign and protolanguage

What is missing includes:

A concern with prosody and the musical aspects and linkages of language

A promising observation: Embodied language evolves in time so that the necessary brain mechanisms are in place to adjust tempo and its variation

The Mirror System Hypothesis: *Language is a **multimodal system***

- it evolved via many stages,
- much of what we now think of as essential to language is post-biological

A Possible Corollary for Discussion: To place music in evolutionary perspective we must view it as *a **multimodal system*** in which movement of body and voice are intertwined

- it evolved via "protodance" as much as "protosong",
- much of what we now think of as essential to music is post-biological

Darwin on "Language" in The Descent of Man (1871)

1. **A greater development of proto-human cognition**
   - Counter-point: an expanding spiral between protolanguage and cognition
2. **The evolution of vocal imitation** used largely "in producing true musical cadences, that is in singing". He suggests that sexual selection played a crucial role – that the capacity to imitate vocally evolved analogously in humans and birds.
   - Counter-point: sexual dimorphism is strong in birdsong, weak in human language
3. **Meaningful words would then emerge** via "the imitation and modification, aided by signs and gestures, of various natural sounds, the voices of other animals, and man's own instinctive cries"
   - Counter-point: The semantic range here is far narrower than that offered by pantomime.

Tecumseh Fitch and Musical/Prosodic Protolanguage

Fitch offers a modernized version of Darwin's theory which he sums up as

Phonology First

His theory disagrees with mine on two counts:

- He argues that protolanguage evolved in the vocal domain
- He argues that the initial "musical" protolanguage was without meaning

but agrees on one count

- He sees meaning as initially being holistic, associated with phonological patterns, with words emerging from protowords via something like the "Wray-Kirby mechanism"

By contrast I argue for

Semantics First

– pantomime without phonology – then suggest that conventionalization (faster/less ambiguity) led to motor patterns whose fractionation yielded both phonology (duality of patterning) and the passage from protowords to words

Where did Human Song Come From?

At least six species have evolved vocal learning in the context of "song"

- including parrots, songbirds whales, seals, hummingbirds
- … and humans

Fitch: Since it is "easy" to evolve a song system, it makes sense to hypothesize a musical protolanguage in the vocal modality

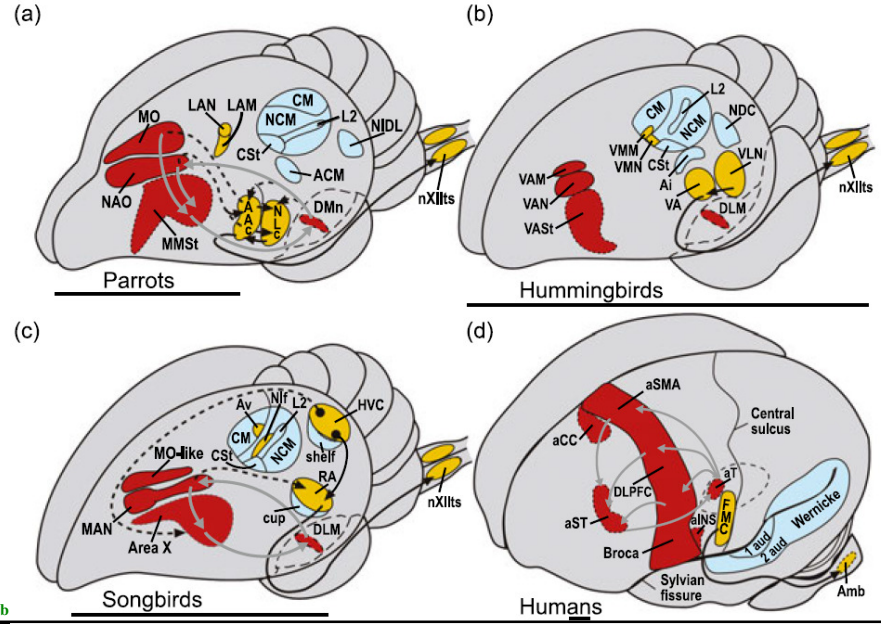
Arbib: Since both manual dexterity and language are unique to humans, it may be the coupling of hand and voice that gave humans the faculty of speech where other creatures have only song.

Alternatives for debate:

- a songlike system and a protosign system emerged independently and then came to reinforce each other;
- evolution of the human articulatory apparatus was greatly facilitated by the emergence of protosign which then catalyzed the emergence of protospeech

In any case, we can learn from songbirds

[Fitch & Jarvis in Arbib (2013) *Language, Music & the Brain*, MIT Press]



Arbib

Current Controversies and the Challenges of Multi-Disciplinary Research

- Isn't it time we abandoned the idea of an innate UG?
- What are the Key Processes that made language emergence, acquisition and use in conversation possible?
- Was the path to speech indirect?
- Is a "words alone" approach viable for evolinguistics?
- Is there an approach to grammar that fits well to the study of brain mechanisms?
- How can niche construction illuminate processes that formed the language-ready (culture-ready/cognition-ready) brain?

- Praxis and Communication
- Social Interaction
- Comparative Neuroanatomy
- Genetics
- Psycho- and Neurolinguistics
- Computer Modeling
- Historical Linguistics
- Language Acquisition
- Emotion and Motivation
- Sign Language
- Apraxia and Aphasia
- Archeology & Anthropology

… and Many More